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HYDRAULIC DIAGNOSTIC MONITORING SYSTEM.(U)

MAY 79 J J DUZICH N62269-78-C-0041

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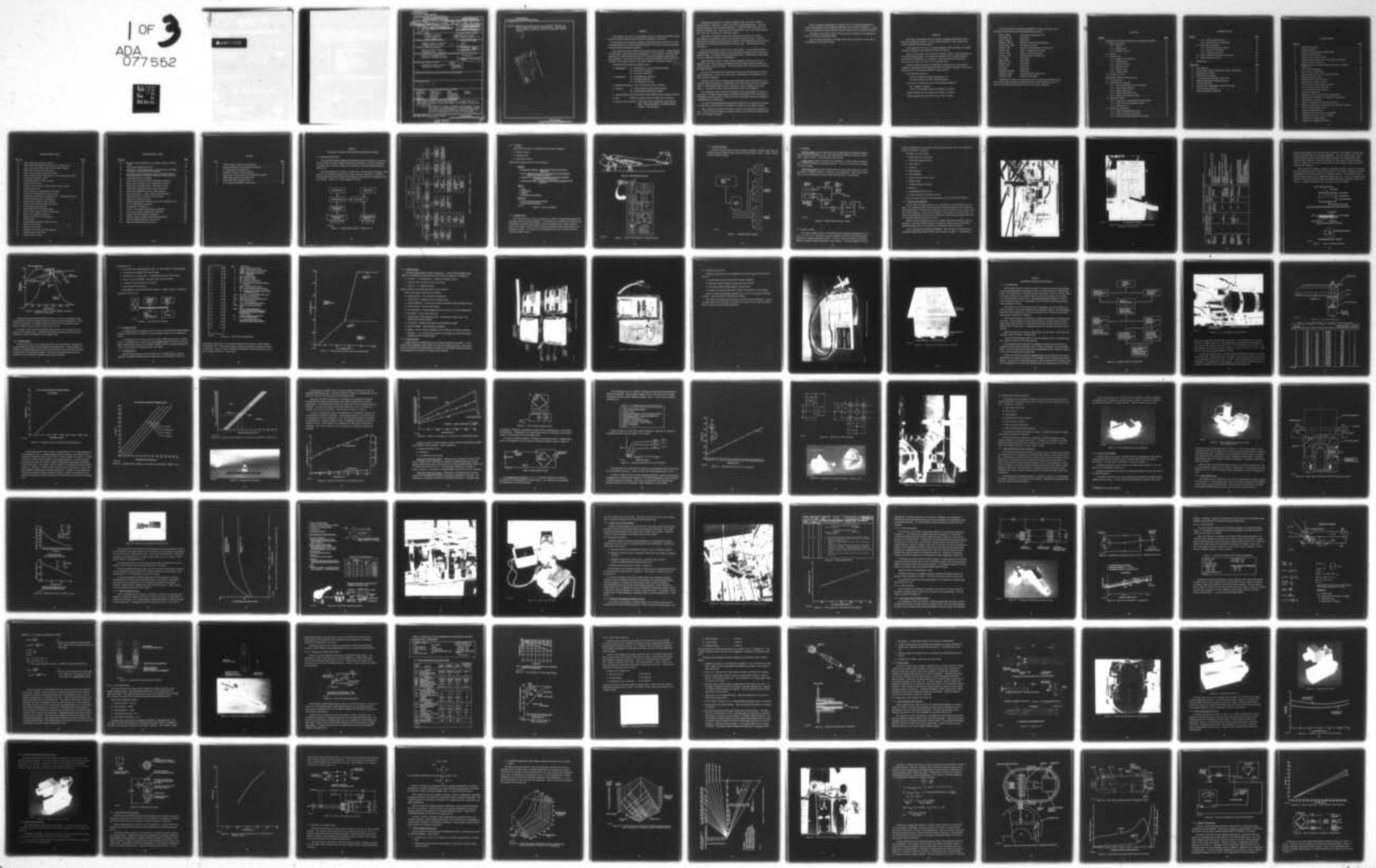

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER (19) TR-76389-30	2. GOVT ACCESSION NO. (9) Interim rept. Nov 77-Dec 78 on / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) HYDRAULIC DIAGNOSTIC MONITORING SYSTEM. ~~TASK I & II INTERIM REPORT~~	5. TYPE OF REPORT & PERIOD COVERED TASK ~~I & II INTERIM REPORT~~ 1 and 2
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) JOHN J. DUZICH	8. CONTRACT OR GRANT NUMBER(s) (15) N62269-78-C-0041 new
9. PERFORMING ORGANIZATION NAME AND ADDRESS Grumman Aerospace Corporation Bethpage, New York 11714	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (11)
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Air Systems Command Washington D.C. Code 340	12. REPORT DATE 31 May 1979
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Naval Air Development Center Warminster, Pennsylvania 18974	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release
Distribution Unlimited

(12) 246

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

(cont. fr p 1)

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hydraulic	Temperature	Pumps	Analog
Monitoring	Fiber Optics	Displacement	Discrete
Flow	Reservoir	Accumulators	
Level	Desiccant	Microprocessor	
Pressure	Filters	Display Panel	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents a twelve month summary of a two year effort of a HYCOS Hydraulic Diagnostic Monitoring System. The program is broken down into three tasks:

Task I encompassed the design, development and procurement of hardware, sensors and microprocessors for two diagnostic monitoring systems. The first system was installed on the F-14 Hydraulic Flight Simulator on Task II of the program. (over)

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20. Task II Installed one system on the F-14 A Hydraulic Simulator for System component reliability demonstrations. The task also covered simulated component failures and diagnostic system reaction.

SUMMARY

This program was based on the feasibility study of a hydraulic monitoring system described in NADC report number TR75168-30 published in July 1976.

The purpose of the Hydraulic Diagnostic Monitoring System (HYCOS) is to warn of impending failure of hydraulic system components by onboard sensors continuously monitoring failure-indicating parameters.

The monitoring system consists of three basic types of sensors: analog, discrete, and fiber-optic. These sensors feed information to a self-contained, centrally located display panel through interface circuits that are easily accessible to ground maintenance personnel. The panel has circuit and system test capability which detects malfunctions of the display indicators, electronic equipment, and sensor circuits. → (cont on p1473A)

The Sensor List includes the following types:

- Displacement: (a) Potentiometer - rotary and linear (analog)
  - (b) Photo-optic (reflective)
  - (c) Hall Effect (magnetic)
- Temperature: (a) Pressurized gas (discrete)
  - (b) Bimetallic (discrete)
  - (c) I/C transducer (analog)
- Differential Pressure, Filter: Spring biased piston (discrete)
- Pressure: (a) Gas and spring biased switch (discrete)
  - (b) Semiconductor strain gage (analog)
- Liquid Detection: Fiber-optic probe using refractive index coupling (discrete)
- Flow: Orifice with bypass shunt for higher flows (discrete)
- Desiccant Color Detection: Fiber-optic color transmission using reflected light. Optical properties of irregular granules (analog - color spectrum)

Displacement sensors of the variable-resistance type were used to measure reservoir piston, accumulator, rudder, and rudder pedal displacements. Two other concepts evolved in the accumulator application, a reflective photo-optic type and a magnetic Hall Effect type. Since they are experimental in nature and require development, they were not used in the prototype system.

Three types of temperature sensors (one analog and two discrete) were chosen and utilized in the pneumatic, fluid, and surface temperature circuits. Their performance was satisfactory during simulator testing. Filter differential pressure indicators were of the spring biased magnetically latching type. Their performance was satisfactory.

Two types of pressure-sensor devices were utilized. In one pneumatic circuit, a temperature-compensated pressure switch performed as predicted over a broad temperature range. In another pneumatic hydraulic circuit, a semiconductor strain-gage type also performed according to specification.

Liquid detection circuits in high-pressure pneumatic bottles proved to be a challenge in the area of pressure sealing and liquid detection using the optical properties of liquids, solids, and gases. All major problems were overcome after extensive development effort.

The use of shunt orifice flow measuring devices proved satisfactory in three hydraulic subcircuits. In two of the three cases, the indicator was immobilized to preclude erroneous indication.

Desiccant color detection utilizing color transmission proved difficult due to the irregular desiccant particles and optimization of the light source and sensor reflective angle. A high-intensity light source is required to achieve sufficient color transmission. An improved sensor is being developed for the A-6E installation.

The diagnostic system monitors the hydraulic system during flight as well as on the ground. In flight, discrete failure indications are displayed when the aircraft is interrogated from the ground. Discrete sensors are manually resettable, resulting in extinguishing of the panel lamp.

An onboard preprogrammed microprocessor handles all the analog inputs through A/D converters and determines the condition of components with multiple sensors.

Task I defined and procured hardware sensors for two diagnostic monitoring systems. After individual component acceptance testing, the system was interfaced with the F-14A hydraulic simulator.

Task II consisted of installing the system on the F-14A hydraulic simulator in order to demonstrate system/component reliability under simulated conditions. A base-line was established and various failure mode and diagnostic system reactions determined.

The scope of this Interim Report covers only the development and integration of the F-14 hydraulic monitoring system.

The A-6 system integration and flight testing will be covered in a final report to be published in the Spring of 1980.

PREFACE

This report was parepared by the Grumman Aerospace Corporation under a Naval Air Development Center, Contract Number N62269-78-C-0041, entitled "Hydraulic Diagnostic Monitoring System".

The program was based on a previous feasibility study conducted by Grumman Aerospace Corporation and reported in NADC TR 75168-30.

Task I of this report covers procured hardware, sensors, and microprocessors for two monitoring systems. One system was installed in a F-14 Flight Simulator and the other scheduled for an A6 aircraft. The work reported in this report covers the time frame, November 1977 to December 1978.

Task II covered the results of installing the system in an F-14A hydraulic simulator, integrating and debugging the system and finally simulating various failure modes in order to demonstrate diagnostic system reaction.

The sponsoring agency is:

Naval Air Systems Command, Washington, D.C.
Mr. Steve Hurst, AIR 340C, Program Manager.

The work was administered under the technical direction of:

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Program Manager for this effort is Mr. Edwin A. Anderson

Project Engineer for this contract is Mr. John J. Duzich

The author wishes to acknowledge significant contributions made to this program by the following Grumman participating personnel:

Boyce, Walter	Production, Management Staff
Cannizzaro, Sal	Fluid Power
Carley, William	Fluid Power
Dreksler, Herman	Electronic Design and Development
Duschenchuk, Mike	Electronic Technician
Hartman, Jeff	Corporate Instrumentation, Ground Test
Howard, Bill	Optics, Navigation and Display
Hurley, Frank	Quality Control Laboratory
Kennedy, Bob	Mechanical/Fluid Systems Test
Lee, Leung	Fluid Power
Moore, Walter	Fluid Power
Pellegrino, Joe	Fluid Power
Pinelli, Gene	Fluid Power
Sue, Bing	Fluid Power
Wakefield, Fancher	Fluid Power
Yearsley, William	Mechanical/Fluid Systems Test
Zwolinski, John	Mechanical Technician

I would like to express my appreciation for the support and helpful information on fiber-optic connectors provided by Messrs. Robert Lebduska and D. B. Forman of the Naval Ocean Systems Center in San Diego, California.

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ILLUSTRATIONS (contd)

TABLES

Section 1

HYDRAULIC CHECKOUT/DIAGNOSTIC MONITORING SYSTEM

1.1 SYSTEM DESCRIPTION

The Hydraulic Checkout/Diagnostic Monitoring System (HYCOS) is an onboard ground readout hydraulic checkout system whose function is to warn of impending hydraulic system component failures by continuously monitoring failure-indicating parameters.

The monitoring system consists of sensors and a readout panel containing a microprocessor for analyzing multiple sensor outputs from one component. In addition, discrete inputs and processed fiber-optic signals are generated and displayed on the panel display. Figure 1 is a block diagram of HYCOS.

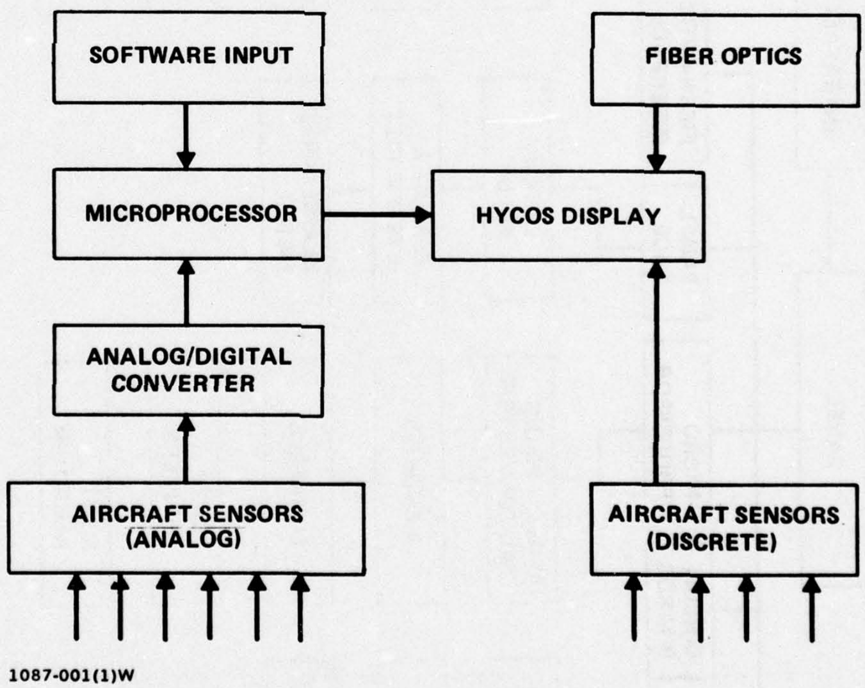

Figure 1. HYCOS block diagram. (Sheet 1 of 2)

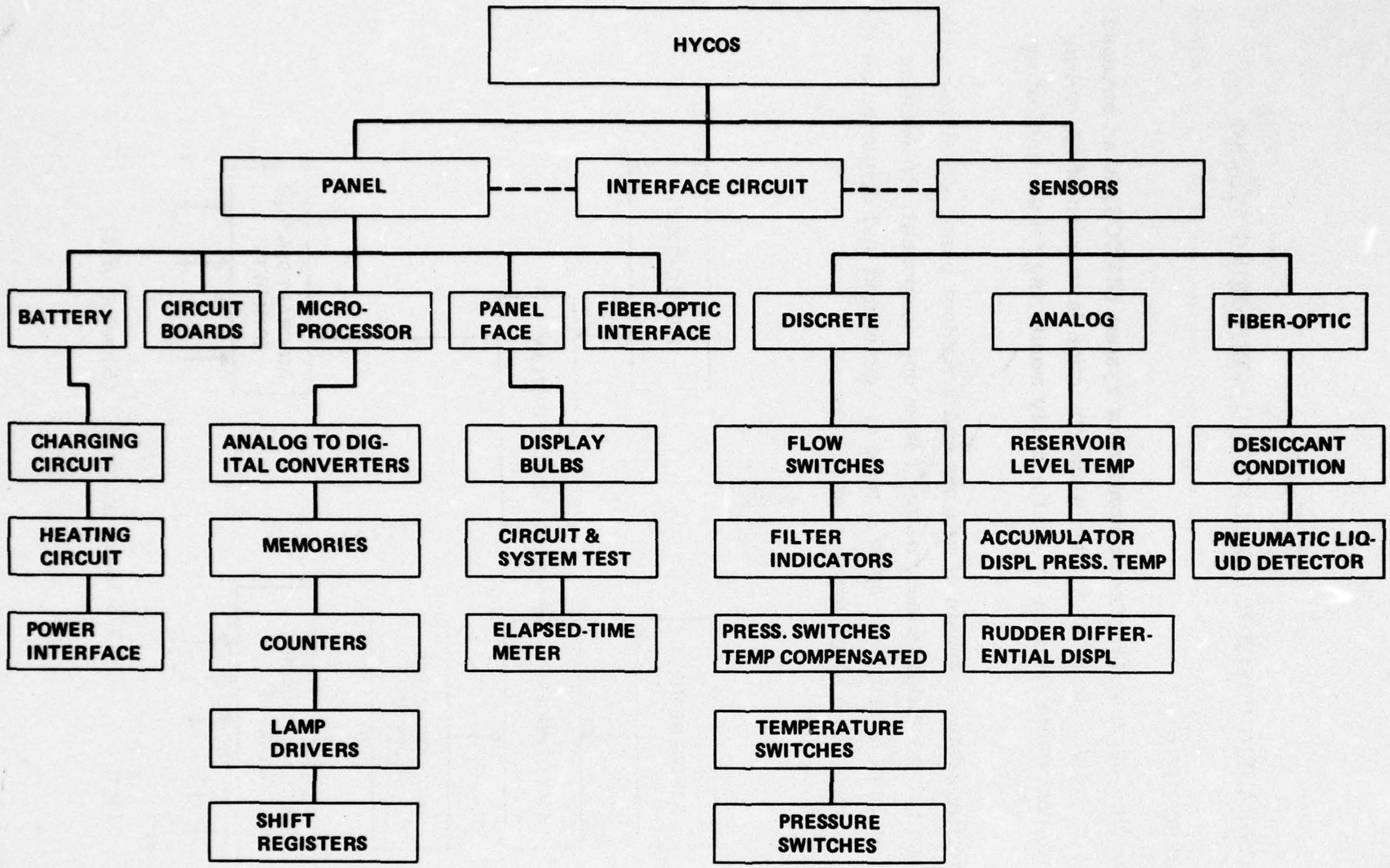

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Figure 1. HYCOS block diagram. (Sheet 2 of 2)

1.1.1 Sensors

The HYCOS sensors are classified into three major categories:

- Discrete sensors
- Analog sensors
- Fiber-optic sensors.

These sensor applications are shown in Figure 2.

DISCRETE

- DIFFERENTIAL PRESSURE – BIASED PISTON USED ON FILTER DELTA-P INDICATORS
- FLOW – BIASED PISTON & VELOCITY HEAD USED ON SYSTEM QUIESCENT, PUMP CASE, & RUDDER ACTUATOR
- TEMPERATURE – EXPANSIVE LIQUID GAS/INTERFACE USED IN SENSING LEAKY MAIN SYSTEM RELIEF VALVE
- TEMPERATURE/PRESSURE (TEMPERATURE-COMPENSATED PRESSURE SWITCH, N_2 BOTTLE)

ANALOG

- LEVEL
- TEMPERATURE
- PRESSURE
- DIFFERENTIAL DISPLACEMENT

FIBER OPTIC

- COLOR REFLECTION (DRIER DESICCANT)
- LIQUID IN PNEUMATIC BOTTLE

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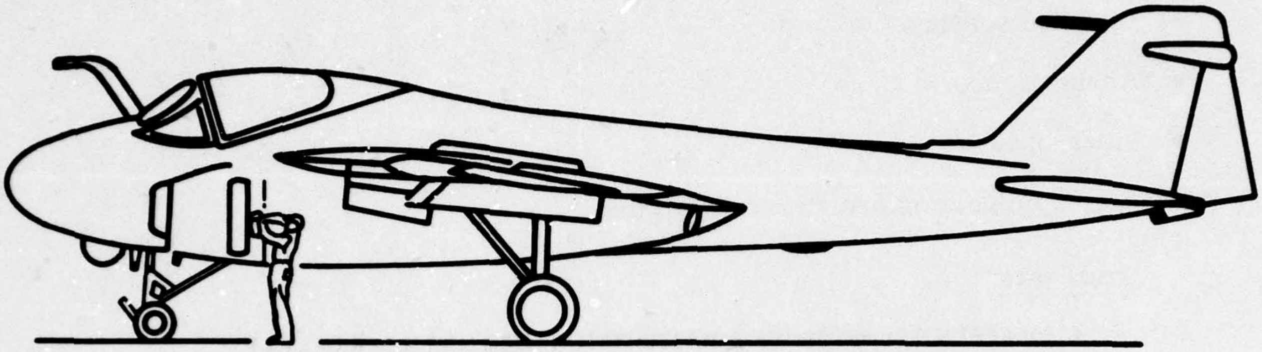
Figure 2. Sensor categories.

1.1.2 Display Panel

The readout panel is a ground-accessible unit which has clearly labeled lights for indicating component failure conditions. The panel is not accessible to the pilot during normal flight, although certain circuits could be interfaced with a caution-warning panel in the cockpit. Figure 3 shows a typical accessible HYCOS panel location on an operational aircraft. The panel can be interrogated both with and without aircraft or ground-support power.



TYPICAL HYCOS ACCESS LOCATION

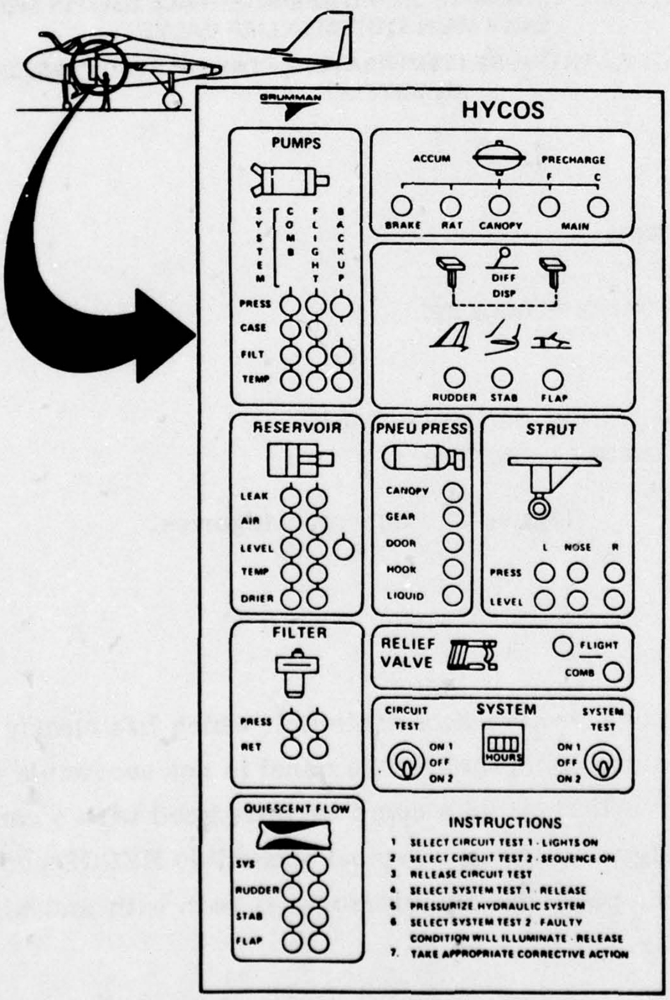


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Figure 3. HYCOS panel location on typical aircraft.

1.1.3 Interface Circuits

Interface circuits consist of power interface, electrical, and fiber-optic lead runs between the power supply display panel and aircraft system sensors. Figure 4 shows a typical interface diagram.

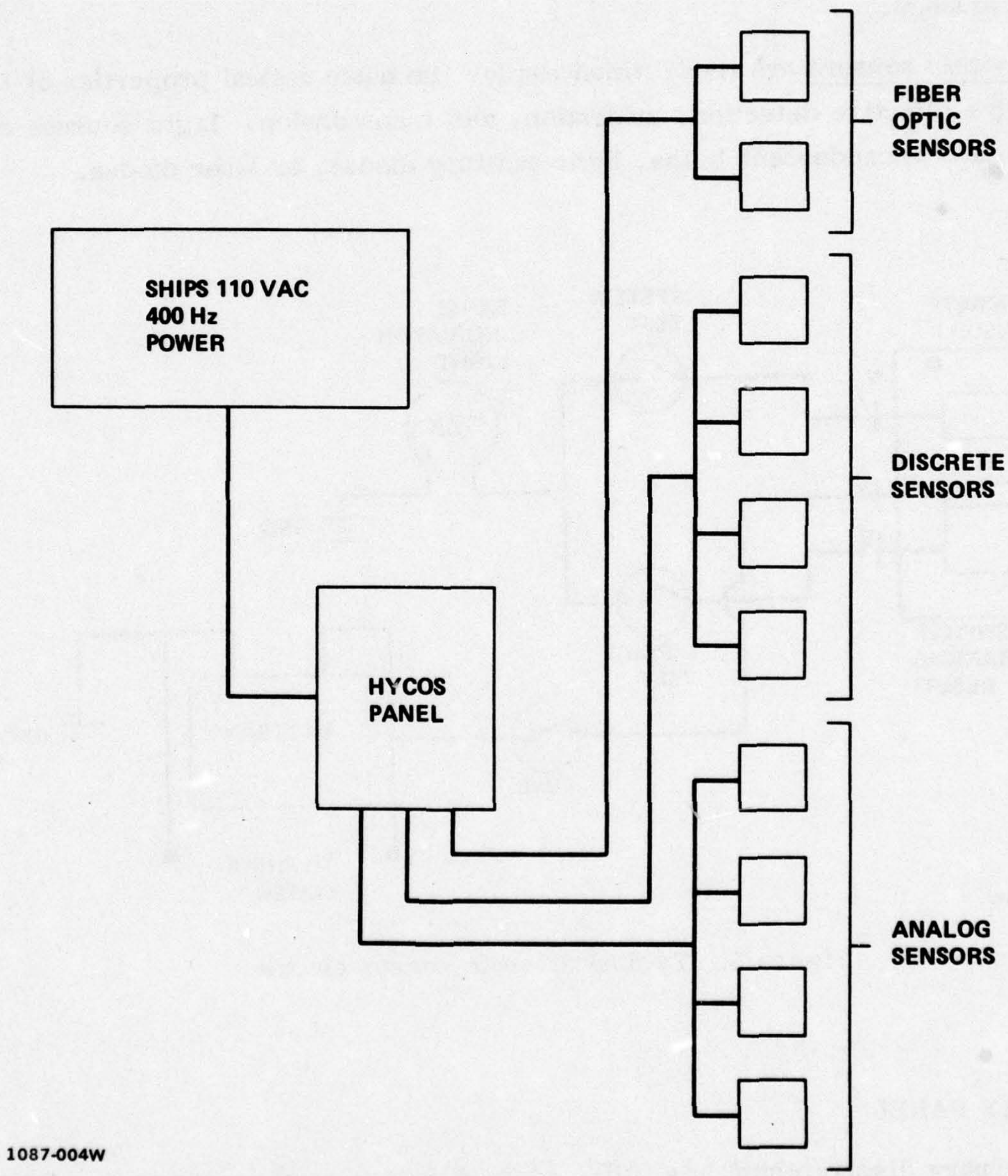

Figure 4. Interface circuit diagram.

1.2 SENSORS

Discrete sensors are of the go/no-go type and generally are manually resetable. When the manual indication is reset, the corresponding electrical circuit also resets itself. Figure 5 shows a typical discrete sensor circuit.

Analog sensors measure varying input conditions or, where multiple parameters exist, define the component operating spectrum. They can be in the form of voltage or current analogs.

Fiber-optic sensors are those which employ the basic optical properties of fluids and solids for effective detection, utilization, and transmission. Light sources could take the form of incandescent bulbs, light-emitting diodes, or laser diodes.

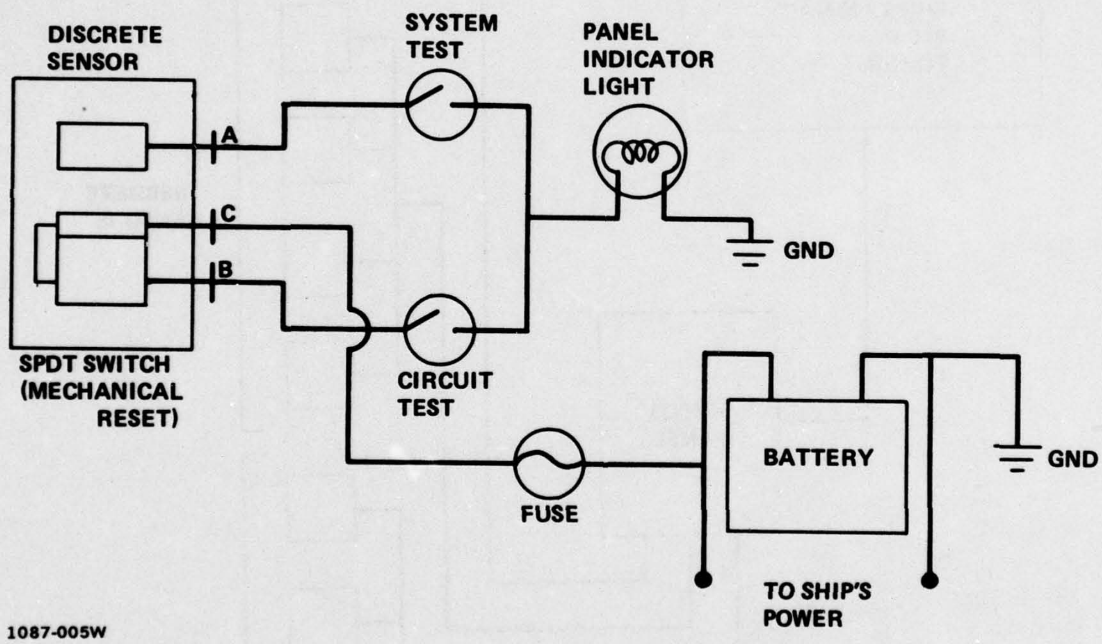

Figure 5. Typical discrete sensor circuit.

1.3 DISPLAY PANEL

The primary display panel is a self-contained unit measuring approximately 12 in. by 6.5 in. by 4.5 in. This size was chosen primarily to fit into an available existing space in the proposed flight-test vehicle. The size, shape, and weight could be configured to specific vehicle installations, when required. The panel weighs 6.0 lb and

contains microelectronic circuits and associated interface items which are described in detail in subsequent subsections.

Basically, the panel houses:

- Display grain of wheat lamps
- Fiber-optic interface outlets
- Lamp drivers
- Counters
- Shift registers
- Power interface
- Sensor and system test circuits
- Microprocessor
- Analog-to-digital converters
- Memories
- Rechargeable NiCd batteries
- Battery heating and charging circuits.

Figure 6 shows the display panel installed on the F-14A hydraulic simulator.

1.3.1 Display Panel Indicators

Several types of display indicators were considered at the beginning of the program. These included LEDs, LCDs, LCDs with backscatter lighting, and subminiature incandescent lamps. Subminiature incandescent lamps are called "grain of wheat" bulbs due to their small size. After careful evaluation, the decision was made to utilize subminiature incandescent lamps since they offer good visibility during daylight and have an acceptable operating temperature range.

LEDs have some advantages but are not readily visible during daylight high-sun conditions. Since the intent of HYCOS is to place the display panel in an external ground-accessible area, the subminiature incandescent lamp was selected.

Table 1 compares the indicators considered. Size-for-size, the subminiature incandescent lamps exhibit good visibility under sunlight conditions. Although their

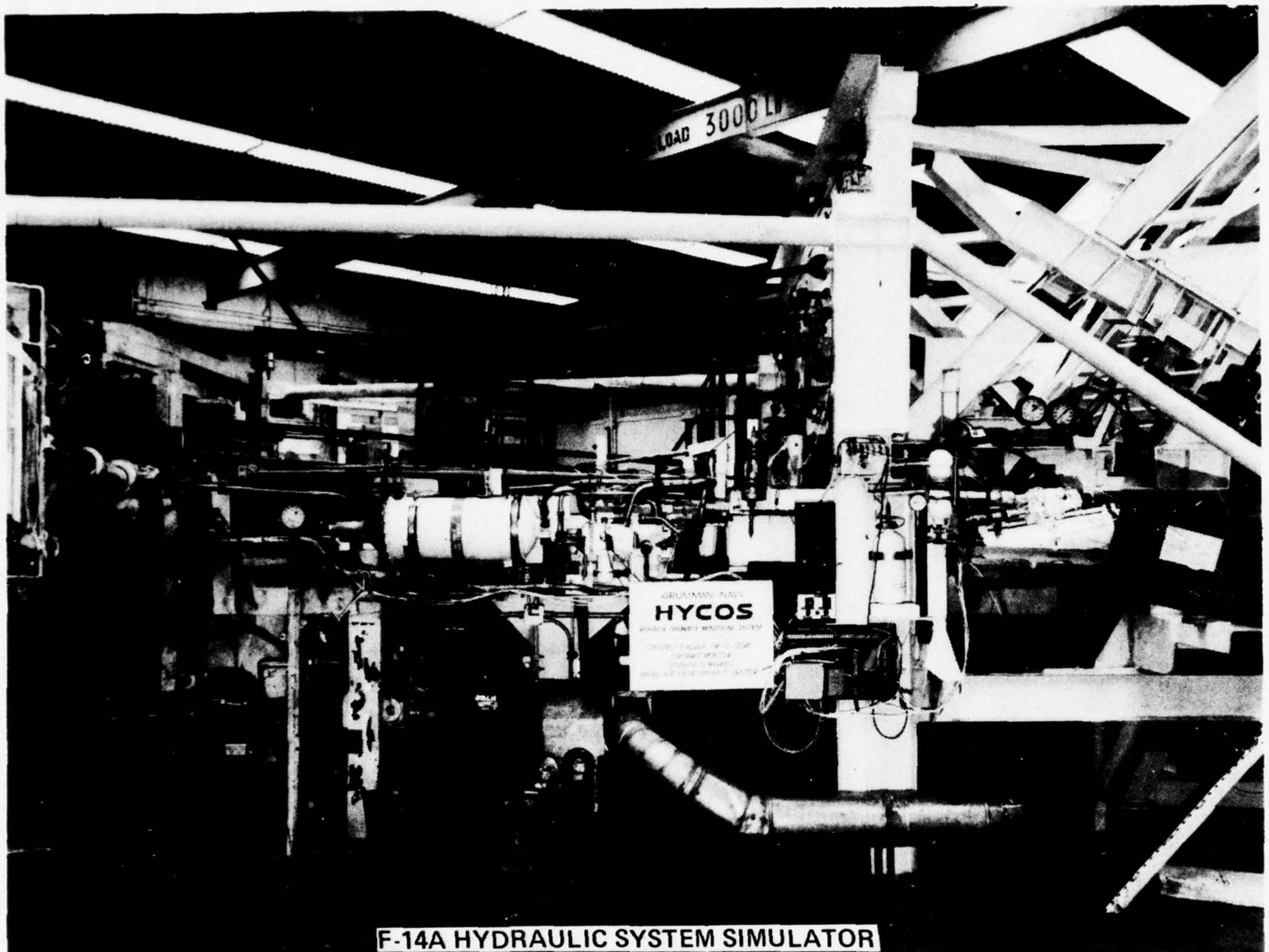

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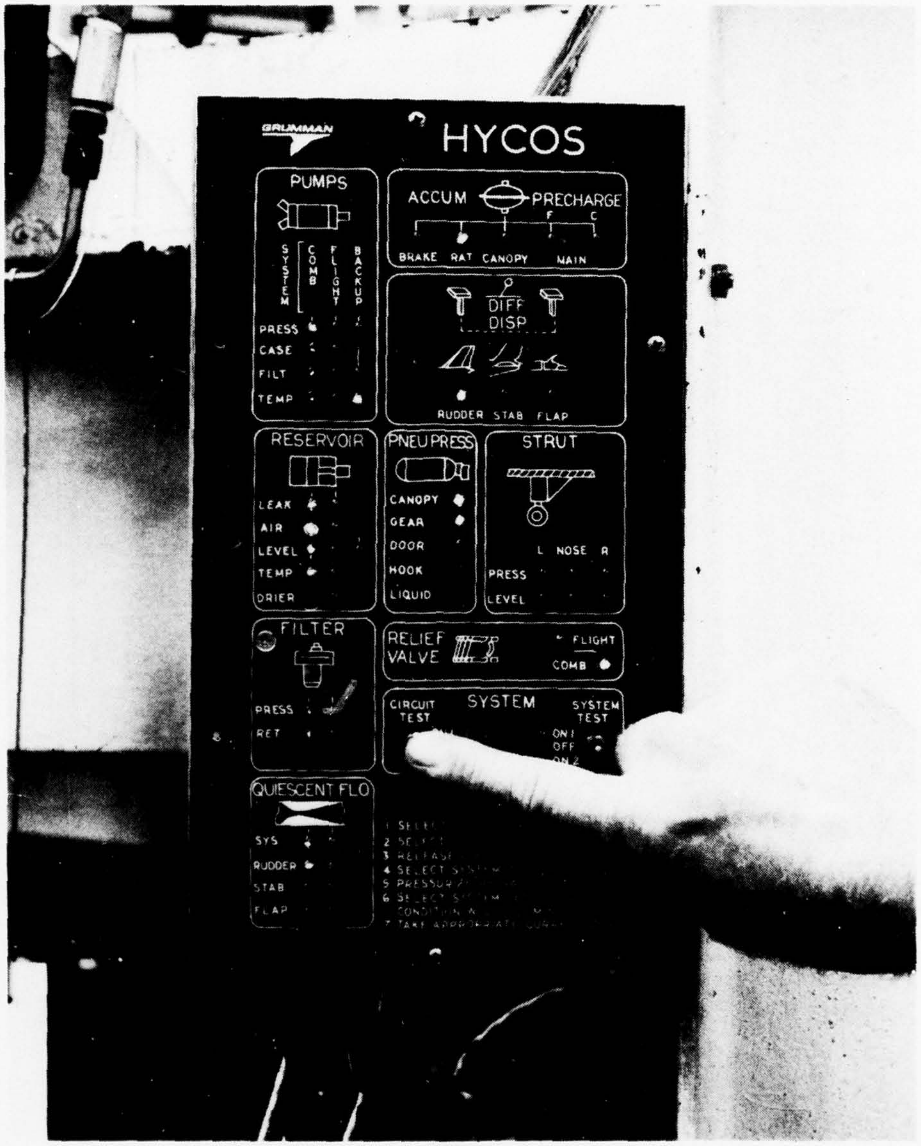
Fig. 6. Display panel installation on F-14A hydraulic simulator. (Sheet 1 of 2)



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HYCOS DISPLAY PANEL

Figure 6. Display panel installation on F-14A hydraulic simulator. (Sheet 2 of 2)

TABLE 1. HYCOS DISPLAY INDICATOR CONSIDERATIONS.

DISPLAY TYPE	POWER REQUIREMENTS		VISIBILITY			COMMENTS
	VOLTAGE, V	CURRENT, mA	SUNLIGHT	NIGHT	BRIGHTNESS	
LED (LIGHT-EMITTING DIODES)	5	20	POOR LIMITED WITH LIGHT FILTER	GOOD	30-300 FOOT-LAMBERTS	• OPERATING TEMPERATURE RANGE: 58 TO 212°F • LONG LIFE • LOW OPERATING VOLTAGE • RUGGED • SMALL SIZE • RESPONSE TIME, NANOSECONDS
LCD (LIQUID CRYSTAL DISPLAYS)	5	30 (6 SEGMENTS)	GOOD	POOR	PASSIVE DISPLAY REQUIRES AMBIENT OR SEPARATE LIGHT SOURCE	• OPERATING TEMPERATURE RANGE: 14 TO 140°F (0 to 60° C) • BECOMES SLUGGISH AT LOWER TEMPERATURES • RELIES ON EXTERNAL LIGHT SOURCE FOR VIEWING AT NIGHT
LCD WITH BACK SCATTER LIGHTING	5	30+ (15 FOR BACKSCATTER LAMP)	GOOD	GOOD TO FAIR	SIMILAR TO INCANDESCANT	COMPLEX, BULKY. TEMPERATURE-LIMITED
SUBMINIATURE INCANDESCANT LAMPS	5	15 TO 60	GOOD	GOOD	> 1000 FOOT-LAMBERTS	• LIMITED BY MULTIPLE LAMP CURRENT DRAIN DURING BATTERY OPERATION • HEAT DISSIPATION A SIGNIFICANT CONSIDERATION • BRIGHTEST OF ALL DISPLAYS • LOW VOLTAGE REQUIREMENTS • RESPONSE TIME IN MILLISECONDS • VIBRATION-RESISTANT IN SMALL SIZES

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current drain is higher than the other types considered, their ability to provide good daylight visibility becomes an overpowering factor. The use of lamps with a 60 mA rating would provide good service life (5000 hr average) and adequate illumination under sunlight conditions. Figure 7 illustrates the basic types of indicator displays (Ref. 5). Figure 8 is a plot of spectral output for various display types as observed by human eye response.

Since as many as 50 display indicators could light up under circuit test conditions, the NiCd battery momentary current drain could be 3 A or higher, neglecting the power requirements for the microprocessor and associated circuits. This conditions occurs when the ship's battery and/or engine electrical power is on. This is a momentary high drain for the NiCd battery and should not significantly affect service life. With ship's power on, adequate monitoring panel and sensor current is available.

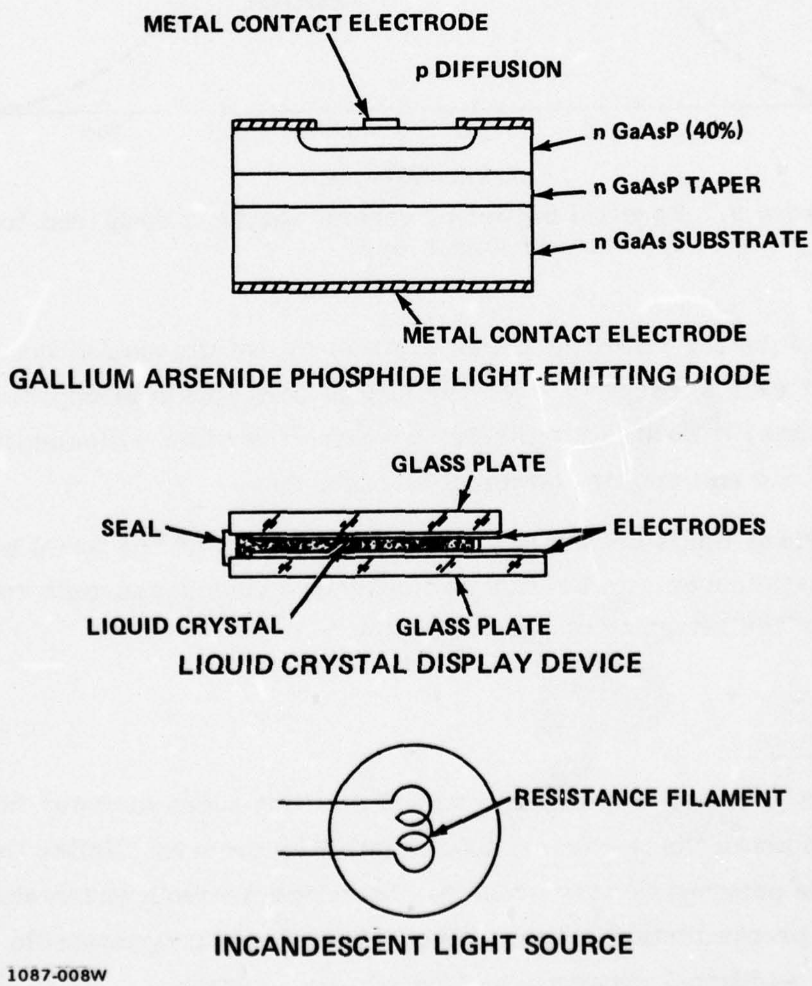


Figure 7. Types of display indicators.

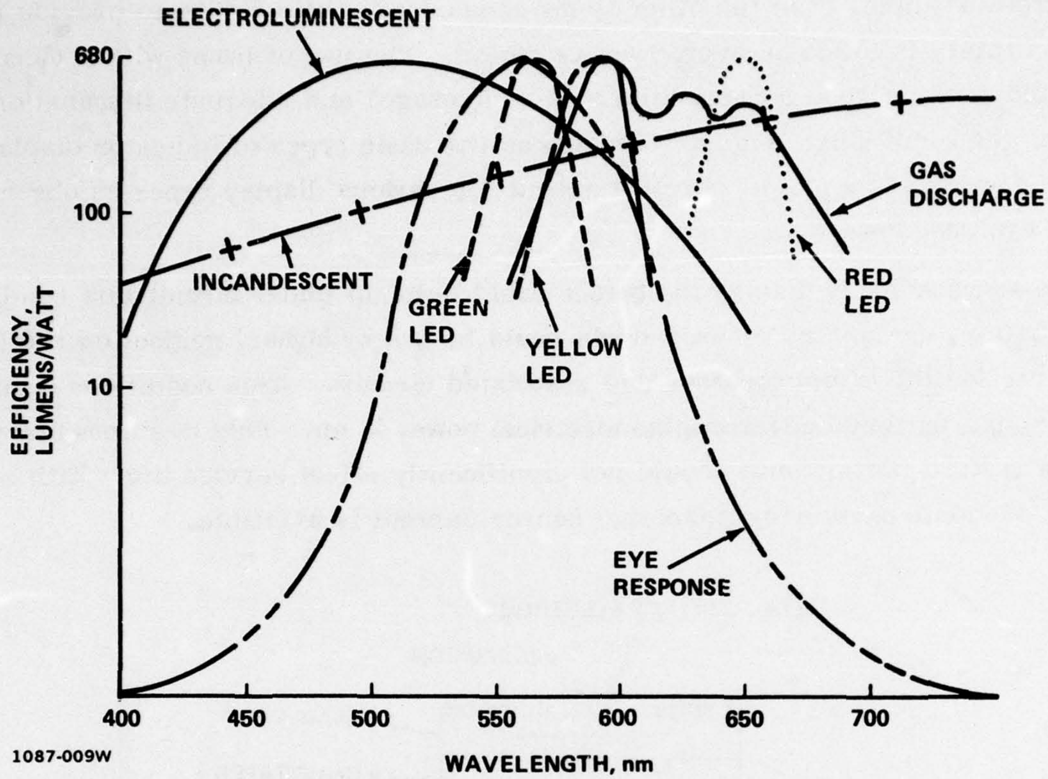


Figure 8. Spectral output of various displays compared to response of human eye.

Another technique for reducing power drain is to use the microprocessor timer to sequentially test each subsection when the circuit test button is depressed. Under system test conditions, it is highly unlikely that more than five components would indicate a failure mode and require power at any one time.

All grain of wheat bulbs are replaceable from the front of the panel by first removing the red plastic cover. Individual and collective circuit and bulb tests can be performed to verify the integrity of each indicator bulb.

1.3.2 Microprocessor

The Intel 8748 (Ref. 2) is a single-component, 8-bit microcomputer fabricated on a single silicon chip using the N-channel silicon gate MOS process. Unlike the 8048, the 8748 has an erasable program memory which can be varied for tests and evaluation during the prototype and preproduction stages. The 8748 is easily programmable and has sufficient room for additional programs and/or add-on functions.

In particular, it:

- Is an 8-Bit CPU containing ROM, RAM, I/0, and a Timer in a single package
- Is powered by a single 5 VDC power supply
- Responds in a 5.0 μ sec cycle. All instructions use one or two cycles
- Has a 1K by 8-bit EPROM, 64 by 8-bit RAM, and 27 I/O lines
- Contains an internal timer/event counter
- Has a single-level interrupt.

A block diagram of the 8748 is shown in Figure 9. Figure 10 shows a typical pin arrangement for this unit.

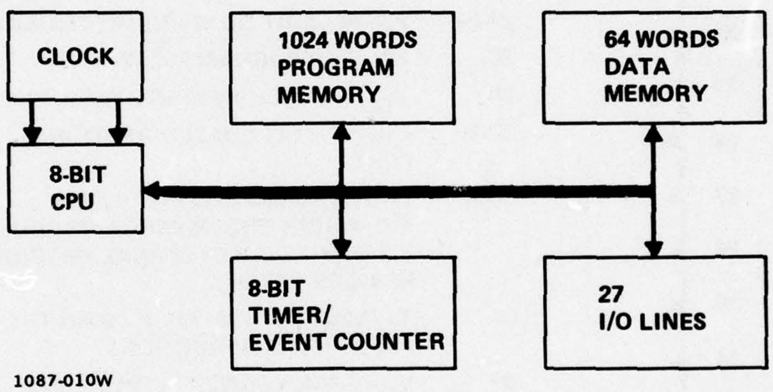


Figure 9. Intel 8748 block diagram.

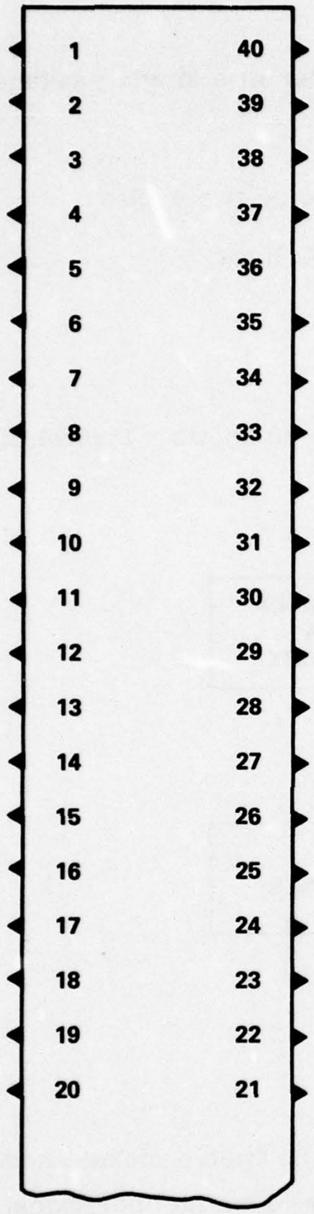
1.3.3 Charging Circuit

A charging circuit was designed into the system to keep the twelve nickel-cadmium batteries charged when the vehicle is on ground-support power or on an operational mission.

A transformer is used to step-down the 115 VAC, 400 Hz power supply. Rectification is accomplished by a diode to a DC value slightly higher than the 5 VDC system. Since nickel-cadmium batteries are difficult to charge below 0°C, external heaters are used to maintain battery temperatures above this value.

1.3.4 Heating Circuit

Since the NiCd batteries must be charged with the vehicle flying at various altitudes, thermostat-controlled battery strip heaters are incorporated. When the



PIN 1	TO INPUT PIN
2	XTAL1 – INTERNAL OSCILLATOR
3	XTAL2 – OTHER SIDE OF CRYSTAL INPUT
4	RESET – INPUT USED TO INITIALIZE PROCESSOR
5	$\overline{\text{SS}}$ – SINGLE STEP INPUT
6	$\overline{\text{INT}}$ – INTERRUPT INPUT
7	$\overline{\text{EA}}$ – EXTERNAL ACCESS INPUT
8	$\overline{\text{RD}}$ – OUTPUT STROBE ACTUATED DURING A BUS READ
9	$\overline{\text{PSEN}}$ – PROGRAM STORE ENABLE
10	$\overline{\text{WR}}$ – OUTPUT STROBE DURING BUS WRITE
11	ALE – ADDRESS LATCH ENABLE OCCURS ONCE DURING EACH CYCLE
12-19	DB_0 – DB_7 – DATA BUS BIDIRECTIONAL PORT
20	V_{SS} CIRCUIT GND POTENTIAL
21-24	P20-P27 8-BIT QUASI-BIDIRECTIONAL PORT
25	PROG – PROGRAM PULSE
26	V_{DD} – PROGRAMMING POWER SUPPLY
27-34	P10-P17 8-BIT QUASI-DIRECTIONAL PORT
35-38	PORT 2 – P20-P23 CONTAIN THE FOUR HIGH-ORDER PROGRAM COUNTER BIT DURING AN EXTERNAL PROGRAM MEMORY FETCH
39	T1 INPUT PIN TESTABLE USING THE JT1 & TNT1 INSTRUCTIONS
40	V_{CC} – MAIN POWER SUPPLY (+5V) DURING OPERATION & PROGRAMMING

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Figure 10. Intel 8748 pin configuration.

temperature drops below 0°, the heating strip functions until the surface temperature reaches 32°F. This thermal cycling enables the batteries to achieve and retain a full charge. Figure 11 shows charging characteristics of NiCd batteries as a function of temperature (Ref. 9, Page 4-36).

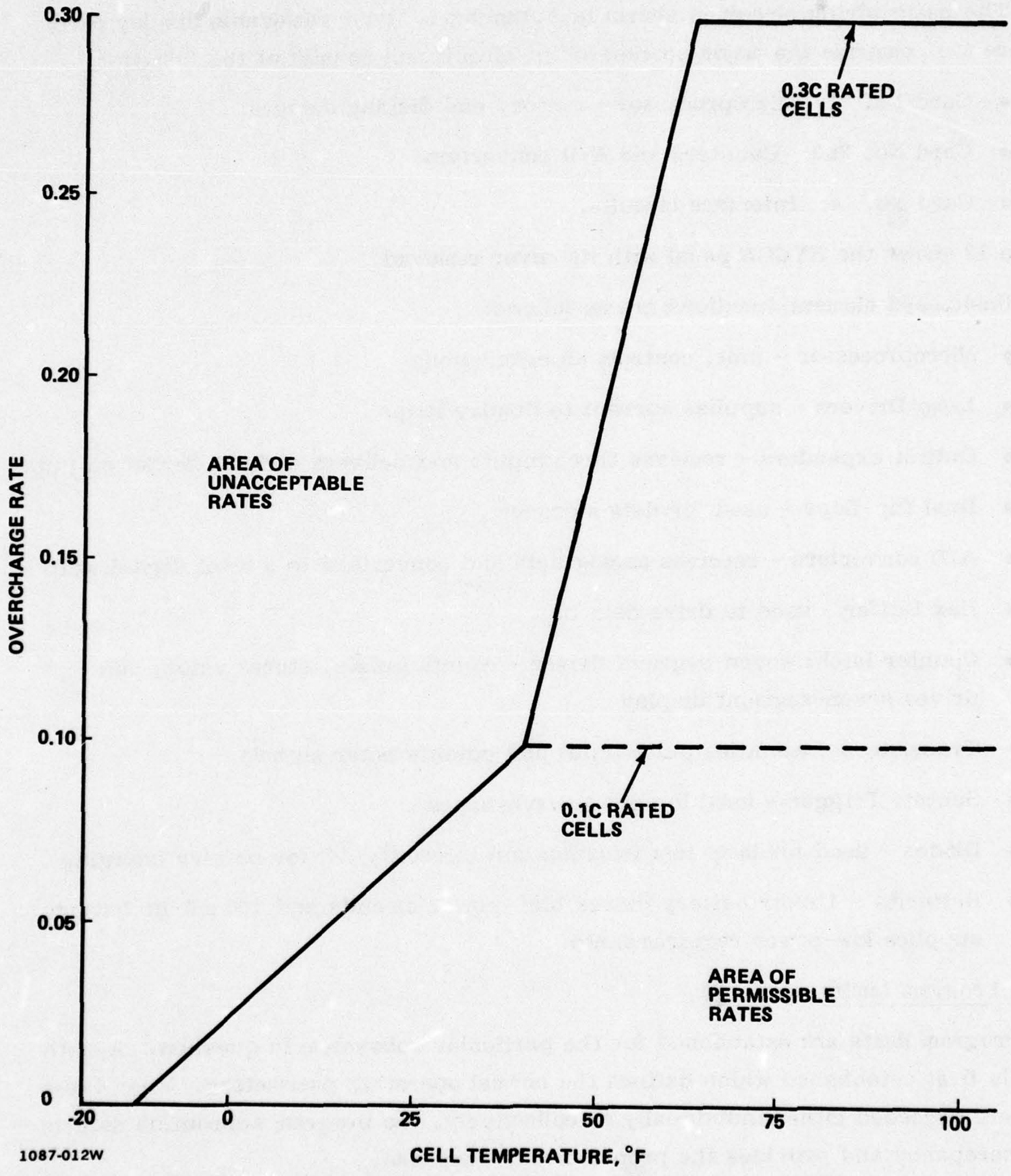

Figure 11. Nickel-cadmium battery charge characteristics.

1.3.5 Wiring Circuit

The basic wiring circuit is shown in Appendix I. Four removable display cards (Figure 12) comprise the major portion of the circuit and consist of the following:

- Card No. 1: Microprocessor - memory and display drivers
- Card No. 2&3: Counters and A/D converters
- Card No. 4: Interface circuits.

Figure 13 shows the HYCOS panel with its cover removed.

Basic card element functions are as follows:

- Microprocessor - unit, controls all calculations
- Lamp Drivers - supplies current to display lamps
- Output expanders - receives three inputs and delivers eight different outputs
- Dual flip-flops - used for data storage
- A/D converters - receives analog data and converts it to a 8-bit digital word
- Hex Buffer - used to drive data bus
- Counter latch; seven-segment driver - counts pulses, stores value, and drives seven-segment display
- Transistors - amplifies pulse input and potentiometer signals
- Schmitt Trigger - used to square waveshapes
- Diodes - used for lamp test isolation and to rectify AC for battery charging
- Batteries - 1 A-hr battery drives high-power circuits and 100 mA-hr battery supplies low-power requiremennts.

1.3.6 Program Limits

Program limits are established for the particular subsystem in question. A math model is first established which defines the normal operating parameters. When these limits are exceeded either individually or collectively, the program subroutine detects the discrepancy and provides the proper circuit response.

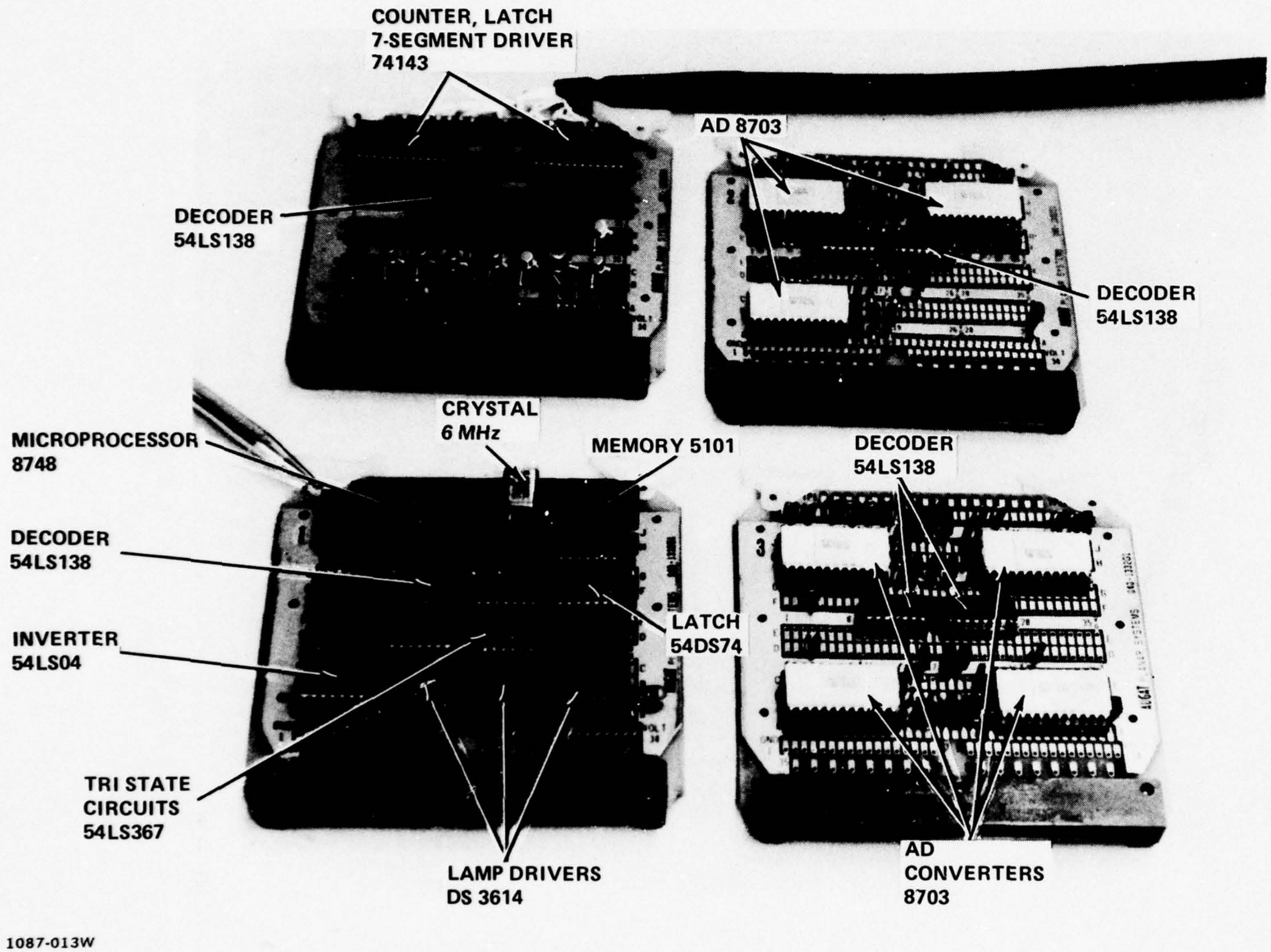

Figure 12. Removable display cards.

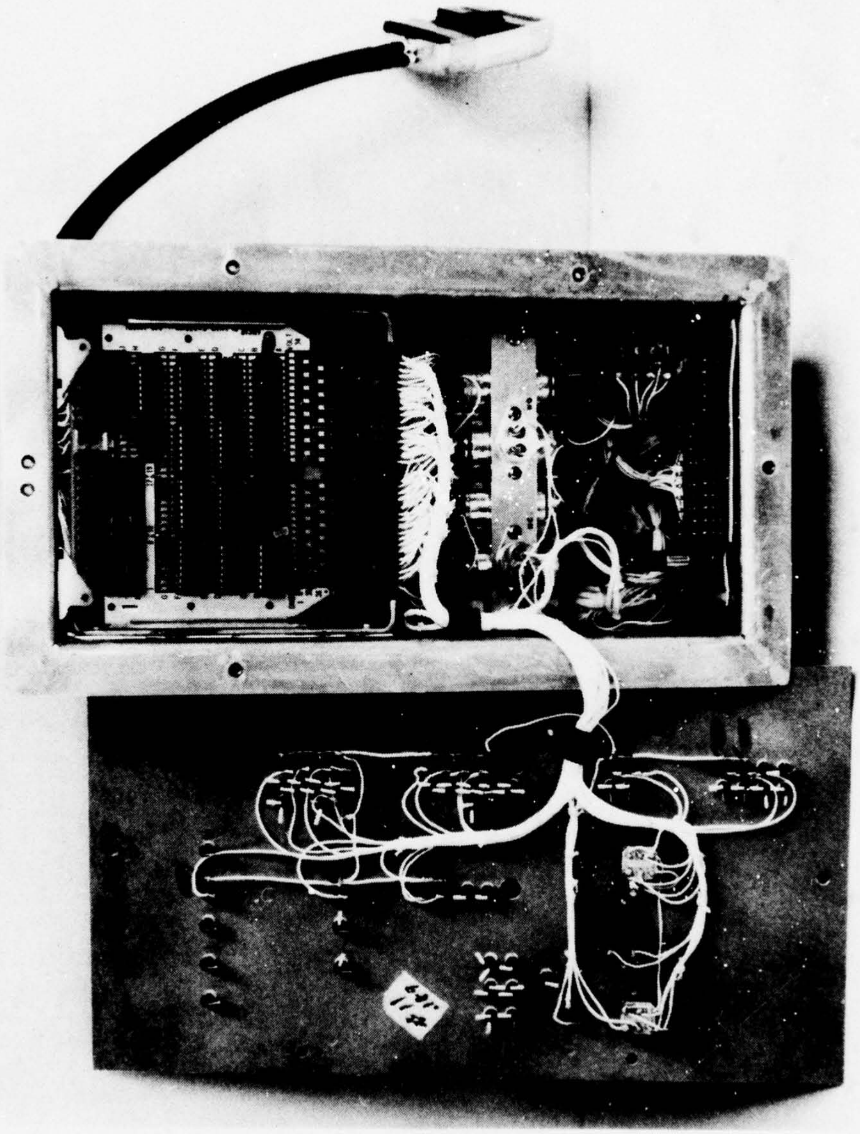

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Figure 13. HYCOS panel with cover removed.

1.4 INTERFACE CIRCUITS

Interface circuits provide the interfacing for all major segments of HYCOS in order to:

- Supply ship's power to the panel for battery charging
- Feed back discrete signals to individual panel elements
- Feed back multiple analog signals to panel circuits
- Supply and feed back fiber-optic signals to the panel for visual display.

Figure 14 shows the interface circuitry used on the F-14A hydraulic simulator interface. Each subcircuit is accessible for testing.

The HYCOS panel bottom has provisions for five interface connectors. Two are for fiber optics, one is for power, and there is one input and one output connector. Figure 15 shows the panel bottom connectors.

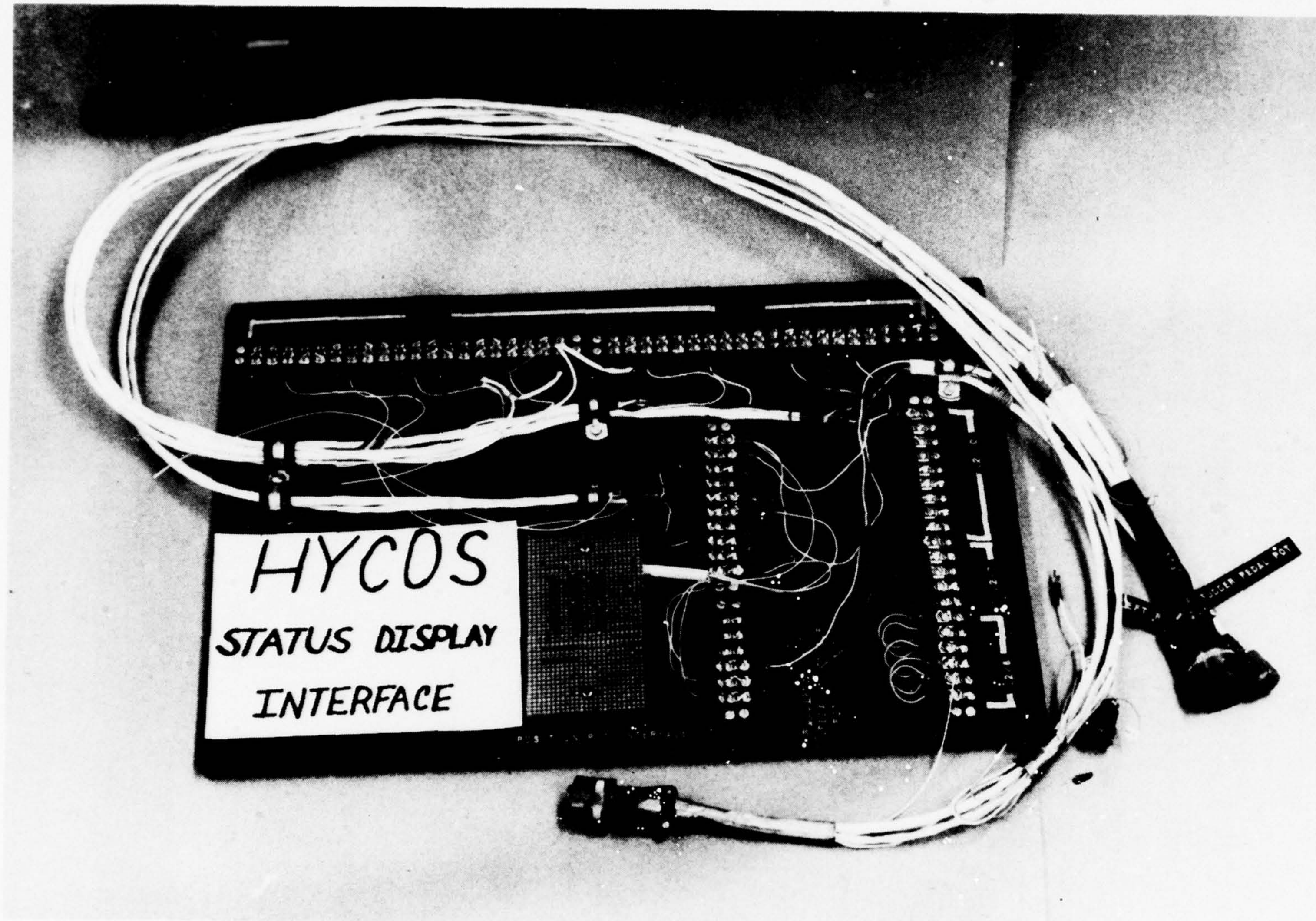

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Figure 14. HYCOS panel interface circuits.

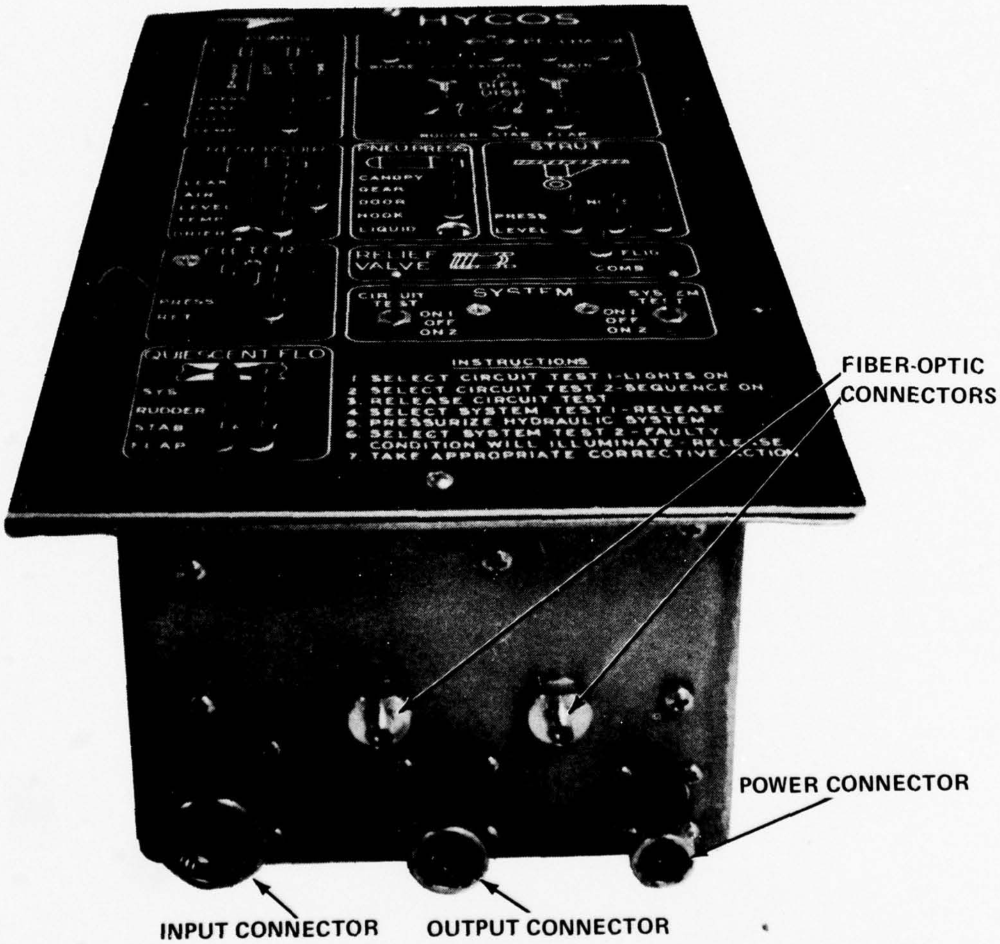

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Figure 15. HYCOS panel showing bottom connectors.

Section 2

COMPONENT SENSOR INSTALLATIONS

2.1 F-14 RESERVOIR

The Combined System reservoir is of the air-oil separated-piston type utilizing bootstrap pressurization by applying the 3000 psi system pressure to a double-side piston. The small piston on the high-pressure side exerts a force on the large piston on the low-pressure side to maintain adequate suction-line pressure to the pumps. The Combined System reservoir has a telescoping high-pressure piston to reduce overall reservoir length and, consequently, has two effective high-pressure piston areas depending on stroke.

The reservoir is of double-wall cylinder construction; the inner cylinder supports the piston and the outer cylinder acts as a pressure vessel. This arrangement protects the inner cylinder from structural deflections due to impacts and loads applied during handling and installation.

Fluid travel indication is provided by a flexible tape calibrated in inches of piston travel. This is attached to the reservoir piston at one end by means of small rollers which allow the piston to rotate without twisting the tape; the other end is provided with a takeup spool. A sightglass allows easy viewing of the tape level indication.

Separate ports are provided for pump suction, system return, relief valve and air bleed, pump case drain, and fluid drain.

A reservoir sensing logic (Figure 16) was developed for the F-14 combined system. Figure 17 shows a view of the reservoir.

The Combined System reservoir was adapted for remote system operation by modifying the tape rollup end spool to drive a small, low-torque, ten-turn potentiometer. The 20 KΩ potentiometer selected for compatibility with the "HYCOS" circuitry is described in Grumman Specification 209.

During the reservoir sensing development phase, it was found that the torque generated by the negator tape spring P/N A51H9089-2 did not develop smooth rotary torque. The result was intermittent irregular torsional movements of the takeup spool and, subsequently, the rotary potentiometer caused by frictional forces in the drive

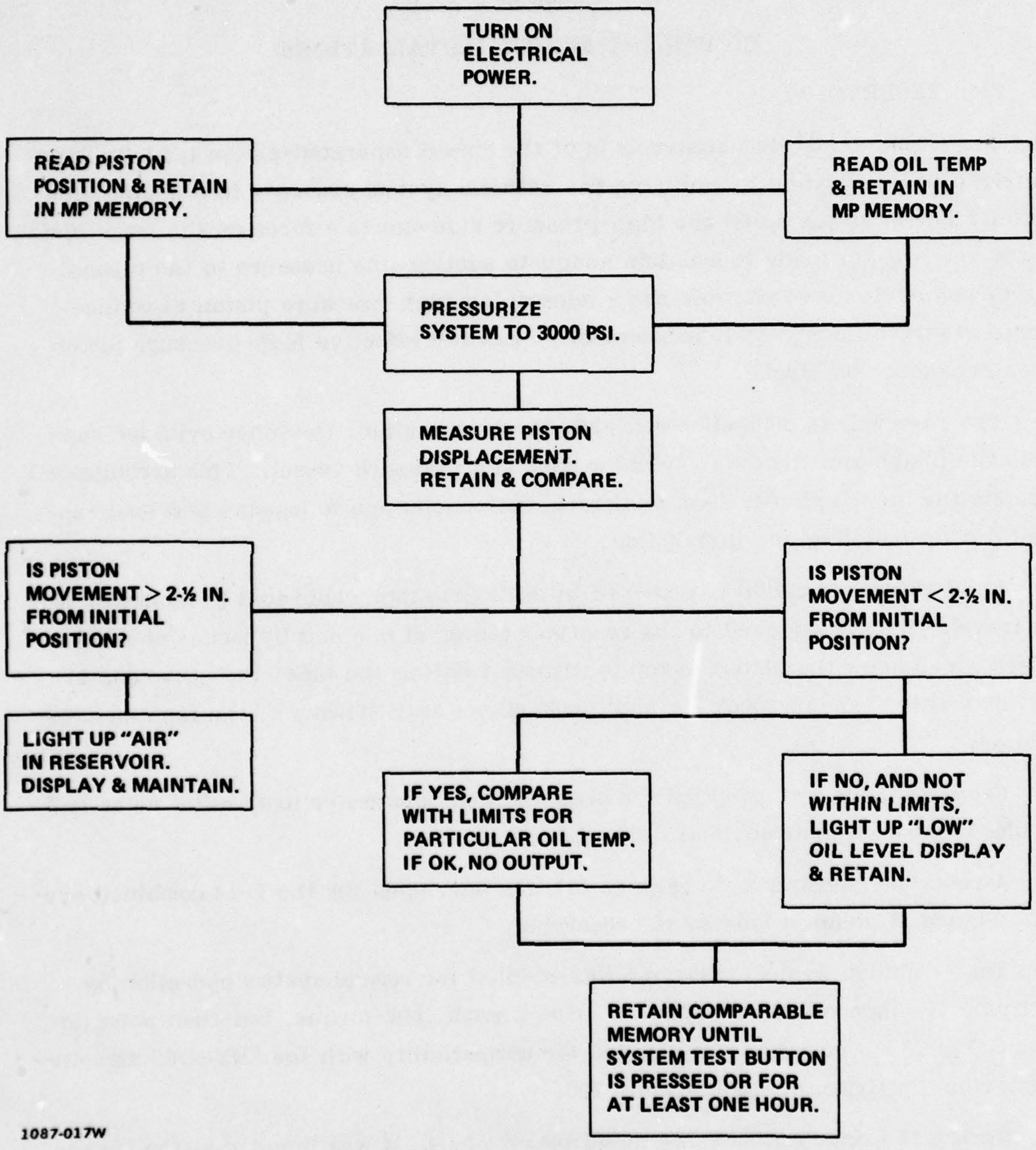
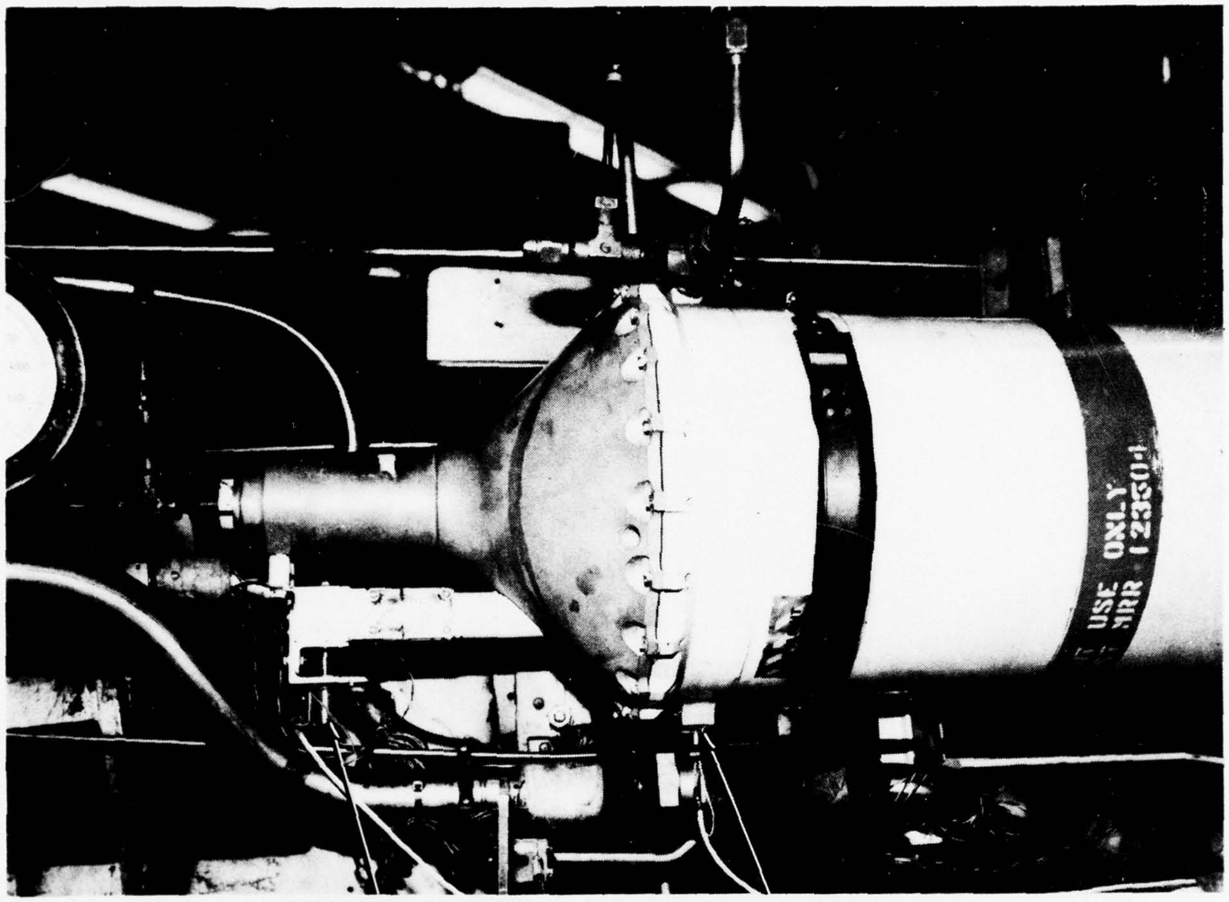


Figure 16. Hydraulic reservoir sensing logic.



PISTON DISPLACEMENT POTENTIOMETER

TEMPERATURE TRANSDUCER

1087-018W

Figure 17. F-14A combined system reservoir.

train even though shaft ball bearings were used. It was concluded that the spring force (i.e., torque) would have to be made larger by increasing the tape thickness. The original tape thickness measured 0.005 in. and developed 0.728 lb of force. The tape thickness was increased by 30% (0.0065 in.), raising the force to 1.60 lb. Figure 18 shows the takeup spool modification in detail.

As with most rollup devices, the linear angular relationship changes as the tape winds upon itself. Initial calculations (see Table 2) were made to determine the impact on an increasing spool diameter due to a 0.005-in. thick tape winding on itself for 20 revolutions. To compensate for this variation, a reservoir with the potentiometer installed was calibrated over full piston displacements (see Figure 19).

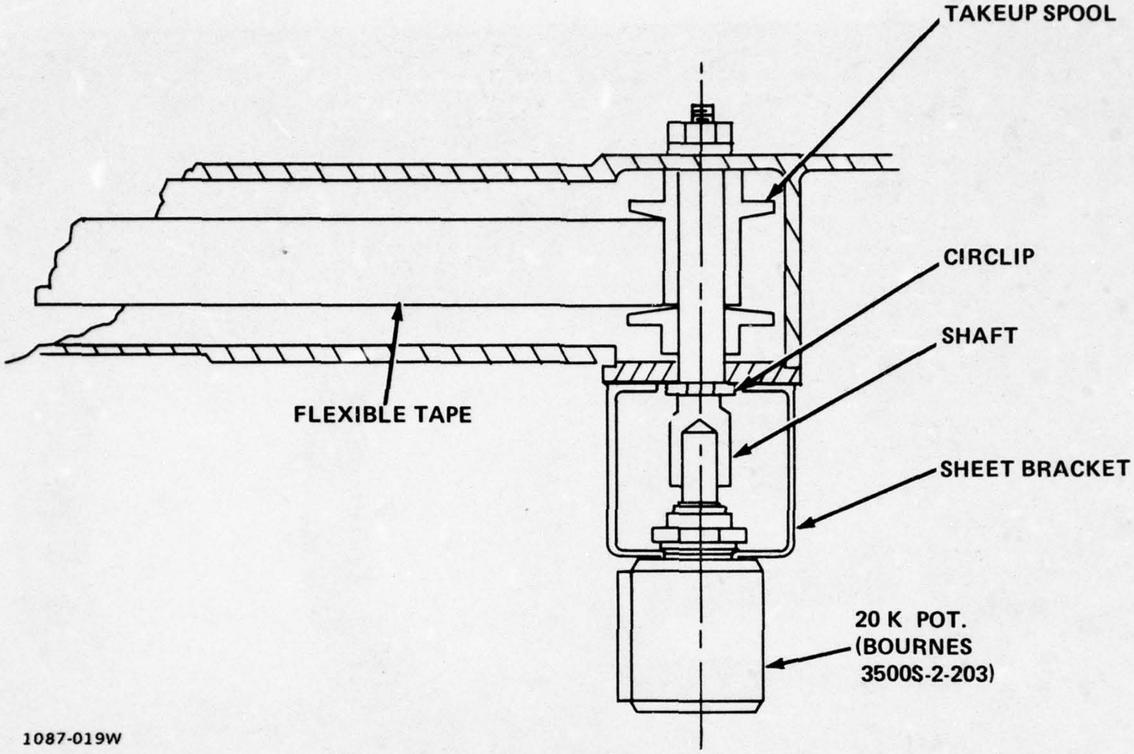


Figure 18. Reservoir displacement.

TABLE 2. RESISTANCE IMPACT OF INCREASING SPOOL DIAMETER.

NO. OF REVOLUTIONS	DIA, IN.	AVG DIA, IN.	AVG DEG/IN.	OHMS READING FOR EACH INCH	READING ON TAPE, IN.
0	0.707	0	162.0819	0.0000	2
1	0.717	0.712	160.9522	893	3
2	0.727	0.722	158.5691	1773	4
3	0.737	0.732	156.4016	2641	5
4	0.747	0.742	154.4472	3498	6
5	0.757	0.752	152.3910	4344	7
6	0.767	0.762	150.3887	5179	8
7	0.777	0.772	148.4415	6003	9
8	0.787	0.782	146.5470	6816	10
9	0.797	0.792	143.9305	7615	11
10	0.807	0.802	142.1213	8404	12
11	0.817	0.812	141.1240	9187	13
12	0.827	0.822	139.4076	9961	14
13	0.837	0.832	137.7355	10725	15
14	0.847	0.842	136.1004	11480	16
15	0.857	0.852	134.5036	12226	17
16	0.867	0.862	132.9415	12964	18
17	0.877	0.872	131.4199	13693	19
18	0.887	0.882	129.9308	14414	20
19	0.987	0.892	128.4701	15127	21
20	0.907	0.902	127.2502	15833	22

1087-020W

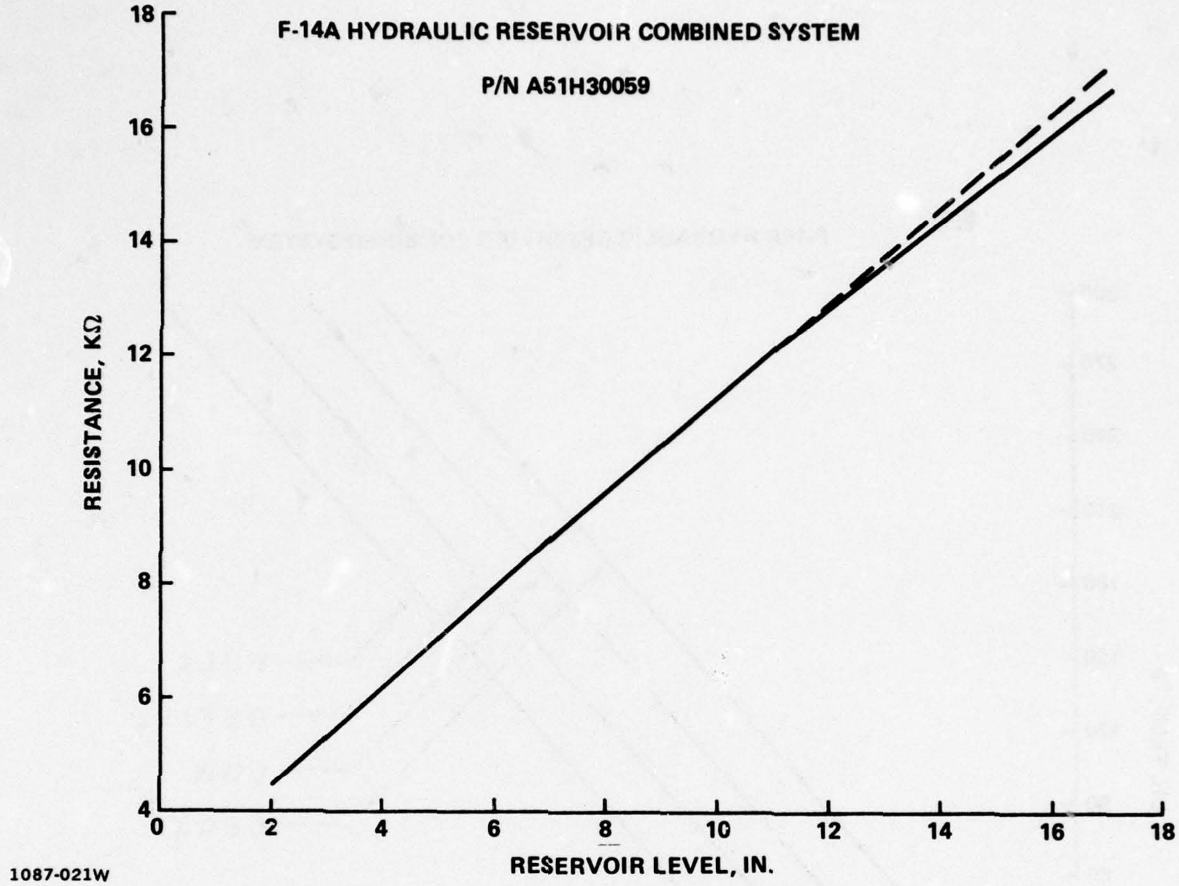


Figure 19. Resistance versus reservoir piston displacement.

Normal reservoir full volume occurs at approximately 5-3/4 in. tape reading at an oil temperature of 70°F. Assuming uniform thermal expansion, the oil volume will increase with temperature rise and vice versa, as shown in Figure 20, Sheet 1. In order to take into account volume changes due to thermal conditions, a reservoir temperature sensor was added to provide a variable analog signal to the signal conditioning circuit in the panel. This sensor, shown in Figure 21, is defined in Grumman Specification 210. Therefore, to detect proper reservoir level, it is necessary to know both piston position (displacement) and fluid temperature. Variation in tape reading due to thermal expansion is shown in Figure 20, Sheet 2. Hence, it is possible for the maintenance specialist to detect low fluid level irrespective of the system fluid temperature.

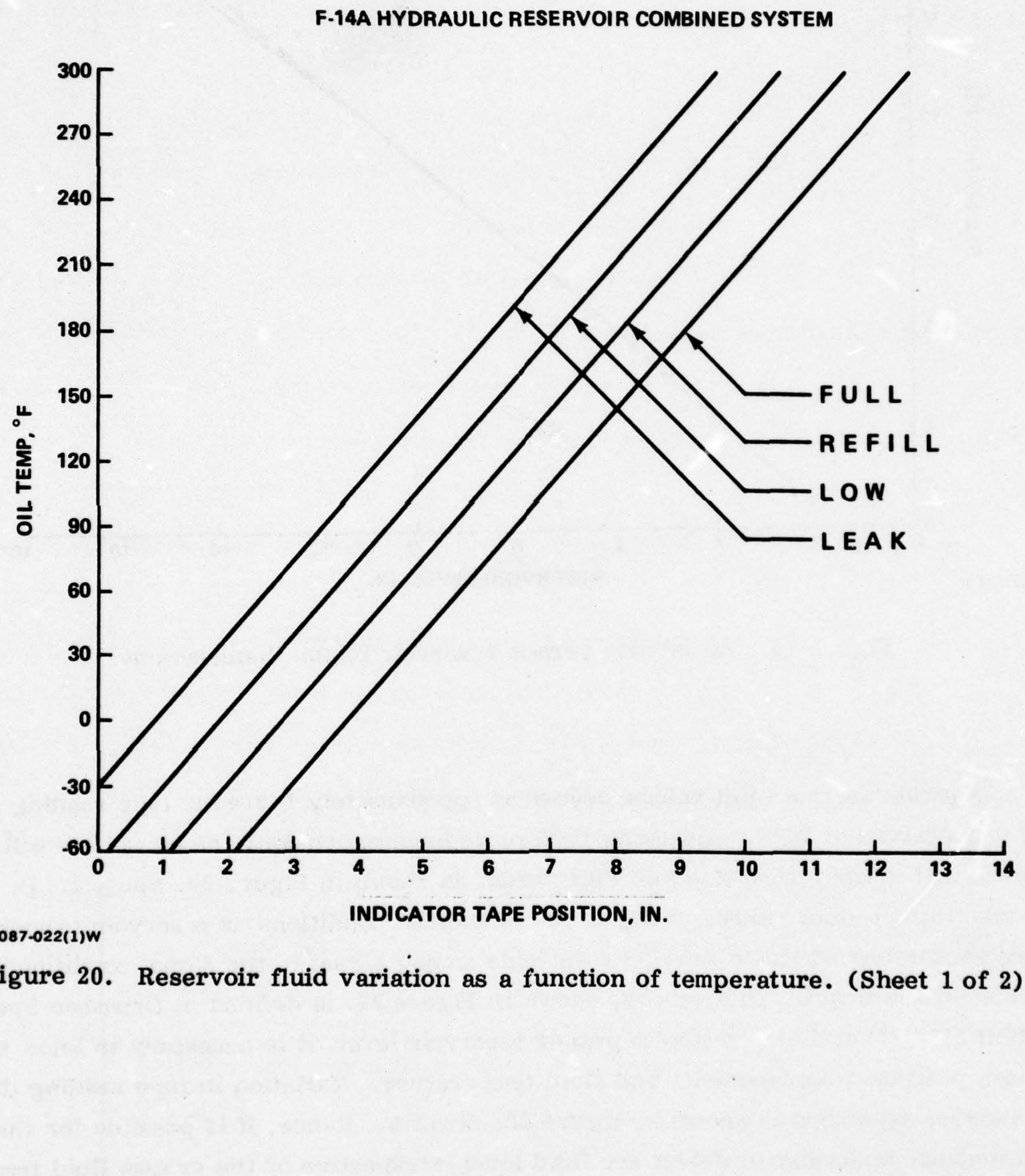
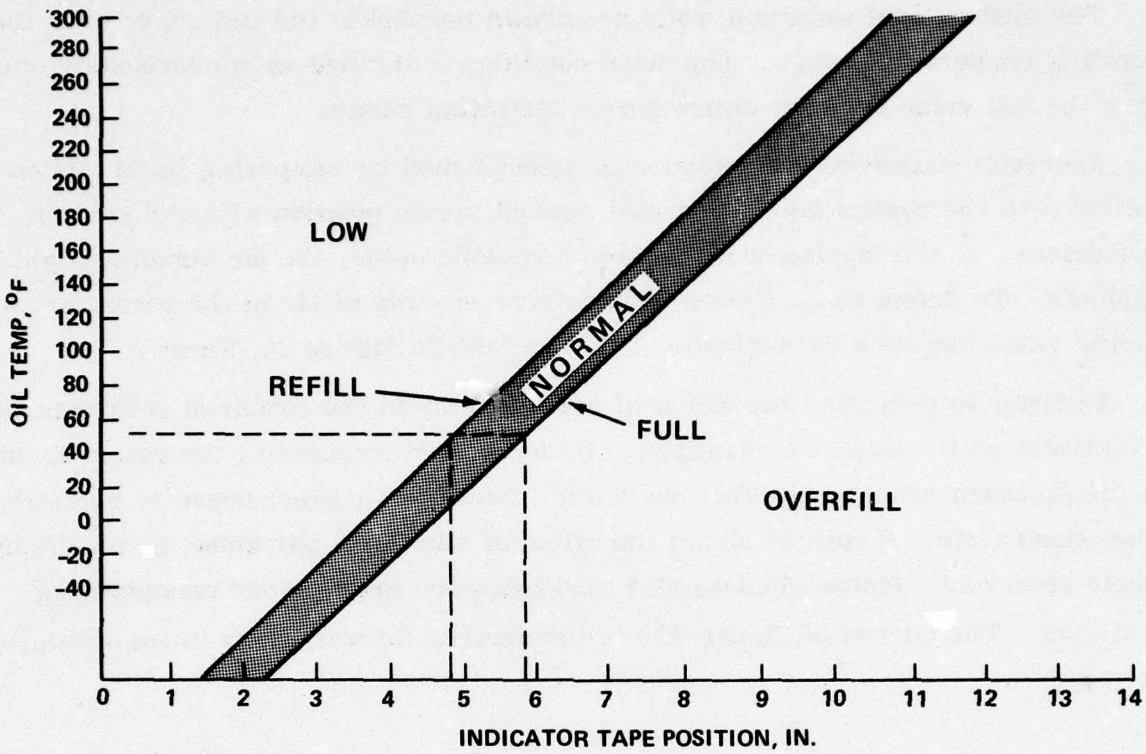
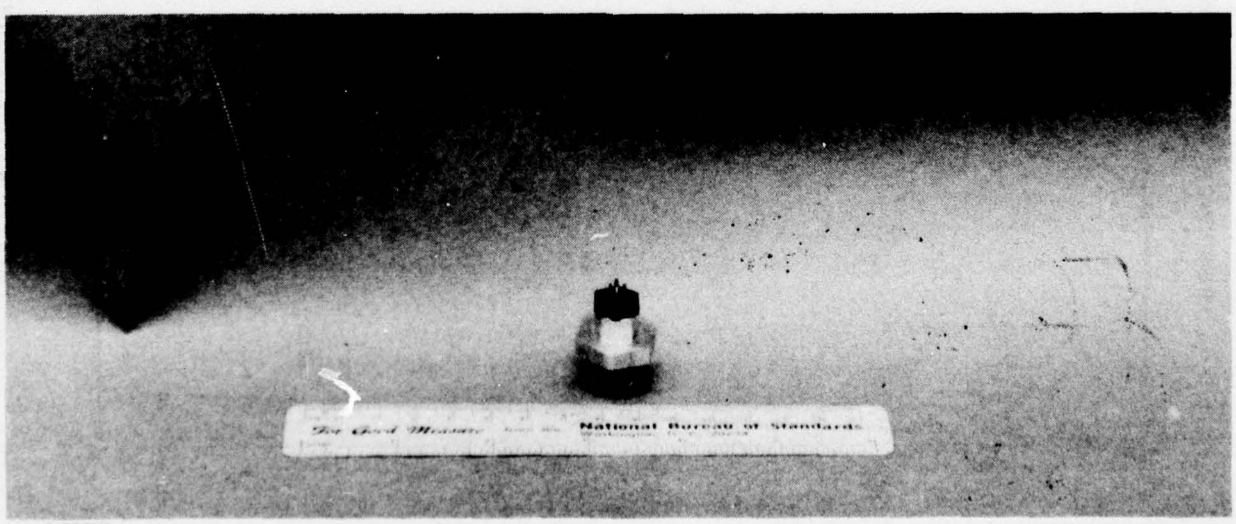


Figure 20. Reservoir fluid variation as a function of temperature. (Sheet 1 of 2)



1087-022(2)W

Figure 20. Reservoir fluid variation as a function of temperature. (Sheet 2 of 2)



1087-023W

Figure 21. Temperature transducer.

The system level condition limits are shown parallel to the full curve over the operating temperature range. Low-level condition is defined as approximately one inch below the full value over the entire normal operating range.

Reservoir-entrained air detection is accomplished by comparing initial piston position with the system nonpressurized against piston position with the system pressurized. If the displacement exceeds a specific value, the air detection light will illuminate. To detect the presence of excessive amounts of air in the reservoir, a specific value has been determined. This is shown in Figure 20, Sheet 2.

In order to determine the effect of entrained air in the combined reservoir, air was introduced in measured quantities. Under normal conditions, the reservoir piston displacement moves approximately 1.9 in. from the nonpressurized to bootstrap pressurized state. Figure 22 shows the effect of additional entrained air on the hydraulic reservoir. Piston displacement readings were taken under nonoperating conditions. The curves of Figure 23 were generated for variations in temperature extremes.

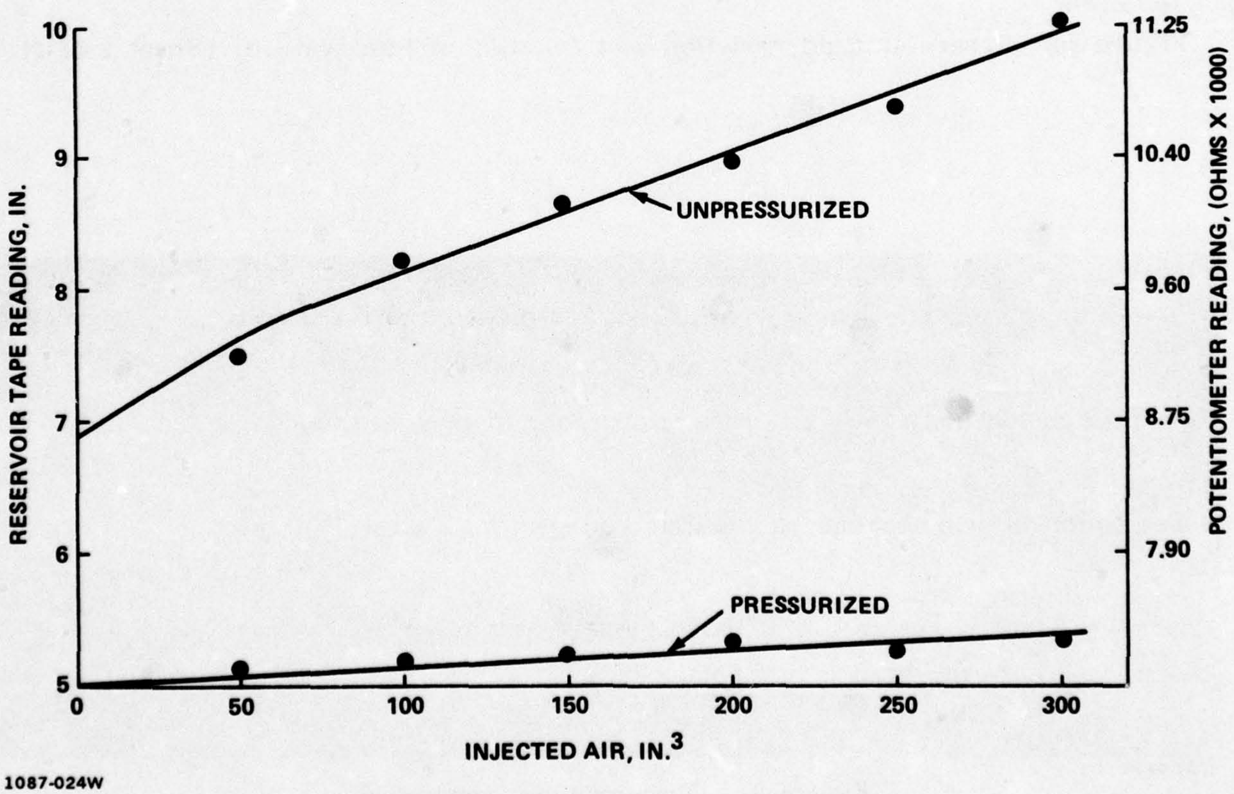


Figure 22. Effect of entrained air in hydraulic reservoir.

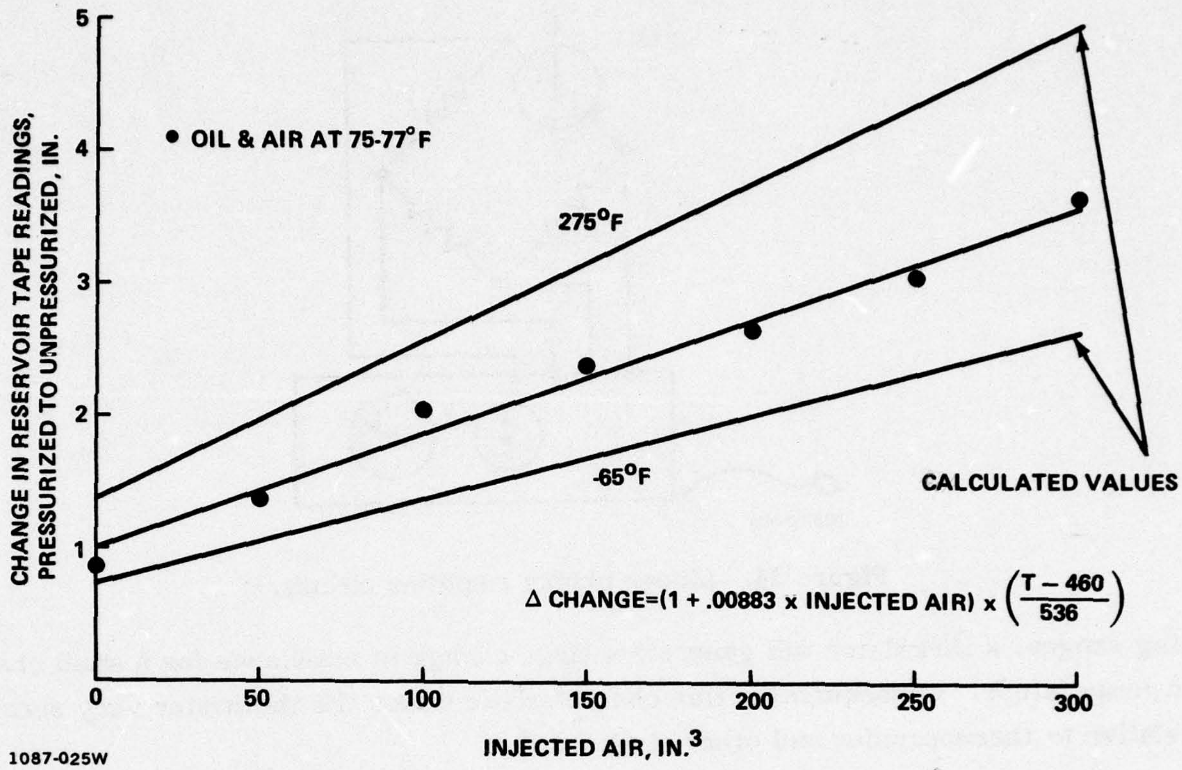


Figure 23. Effect of temperature on entrained air in hydraulic reservoir.

During the course of initial screening, various methods of determining temperature variations were considered. These included the:

- Platinum Resistance Type
- Thermistor
- I/C Temperature Transducer.

Resistance Temperature Sensor. Resistance-type temperature sensors (RTS) such as platinum were considered as candidates for analog temperature sensing. Platinum temperature sensors require the use of a linear bridge amplifier (Figure 24) to condition the circuit prior to use. The temperature coefficient of resistance is positive and linear. The addition of a bridge amplifier circuit adds to system complexity.

Thermistor Temperature Sensor. Thermistors are semiconductors or thermal resistors with substantially high negative temperature coefficients of resistance. The resistance of a thermistor decreases as the temperature increases. In specific opera-

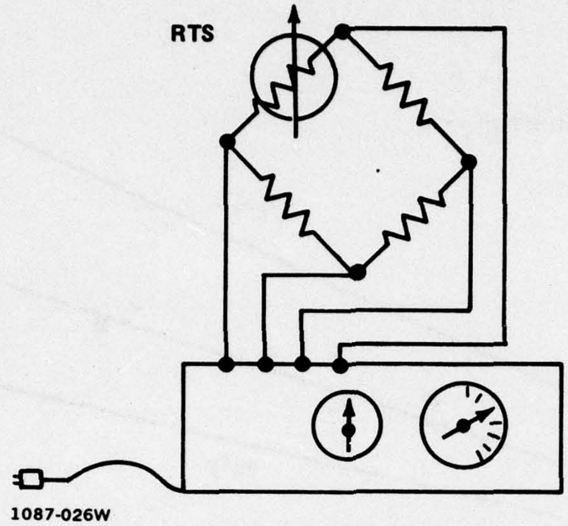


Figure 24. Linear bridge amplifier circuit.

ting ranges, a thermistor will generate a large change in resistance for a small change in temperature. Consequently, this characteristic makes the thermistor very sensitive relative to thermocouples and other similar units.

In order to increase sensitivity, thermistors are normally used in a bridge circuit. That is, the thermistor forms one leg of a Wheatstone bridge as shown in Figure 25.

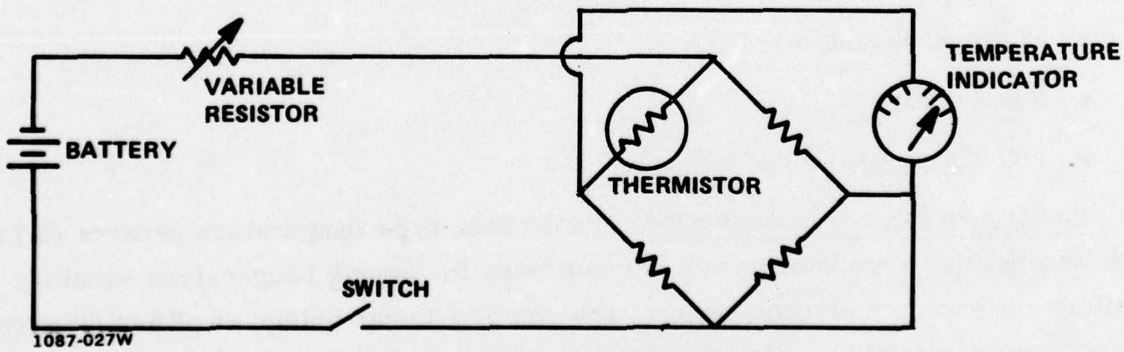


Figure 25. Typical thermistor circuit.

I/C Temperature Transducer. An I/C two-terminal temperature transducer, manufactured by Analog Devices of Norwood, Mass., was evaluated for performance and adaptability to the HYCOS system.

The transducer, part no. AD590.C, produces an output current proportional to absolute temperature. With a supply voltage of 5 VDC, the device acts as a high-impedance, constant-current regulator passing 1 uA/°K. Table 3 shows pertinent technical data.

TABLE 3. IC TEMPERATURE TRANSDUCER DATA.

- TYPE: ANALOG DEVICES AD 590.C
- OUTPUT: 1 UA/°K
- OPERATING TEMP RANGE: -55°C TO 150°C (-67°F TO 302°F)
- TWO-TERMINAL DEVICE: VOLTAGE IN/CURRENT OUT
- CALIBRATION ACCURACY: ±1°C
- LINEARITY: ±0.5°C OVER FULL RANGE
- POWER SUPPLY RANGE: +4 VDC TO +30 VDC
- SIZE: TO -52 PACKAGE

1087-028W

Figure 26 shows a V-I plot for a typical transducer. Note that the current is essentially flat with an input voltage of 3 to 30 VDC.

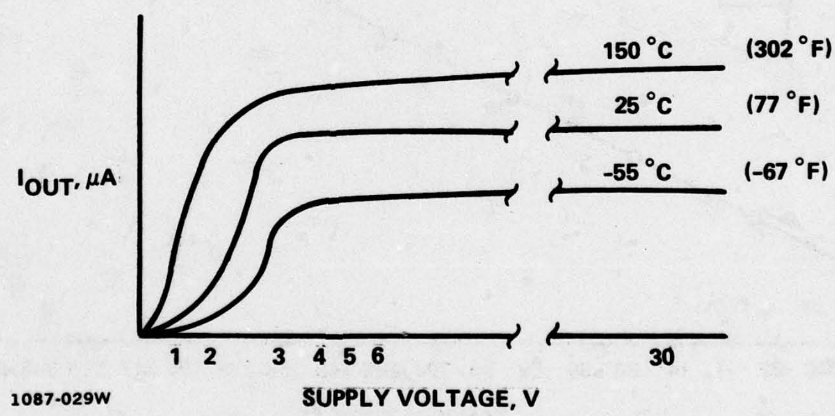


Figure 26. Voltage current plot for an IC transducer.

The transducer was selected for its small size and performance after being tested in the Hydraulic Laboratory. Figure 27 shows the actual calibration for the unit.

In order to adapt the unit to a fluid-sensing application, a pressure housing was manufactured in accordance with Figure 28. The final subassembly is shown in Figure 29 before potting and assembly. This sensor is used both in the reservoir-level sensing circuit and in the accumulator circuit discussed in a later section.

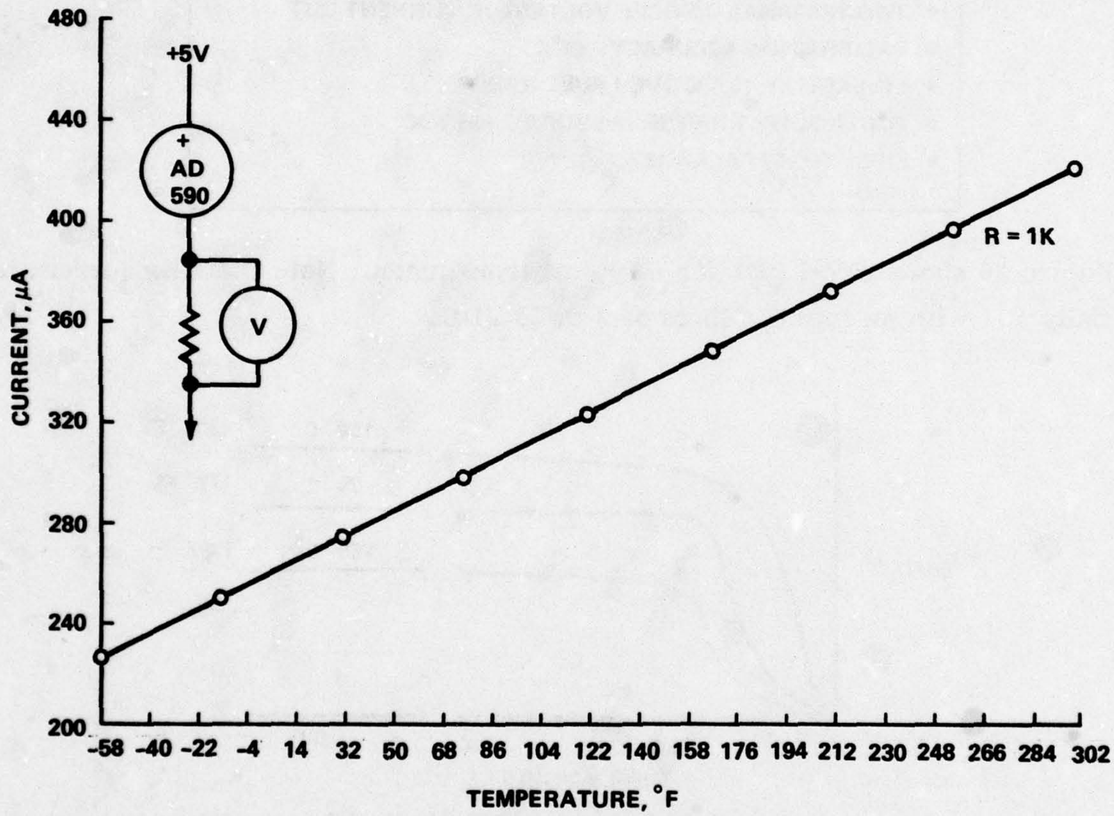
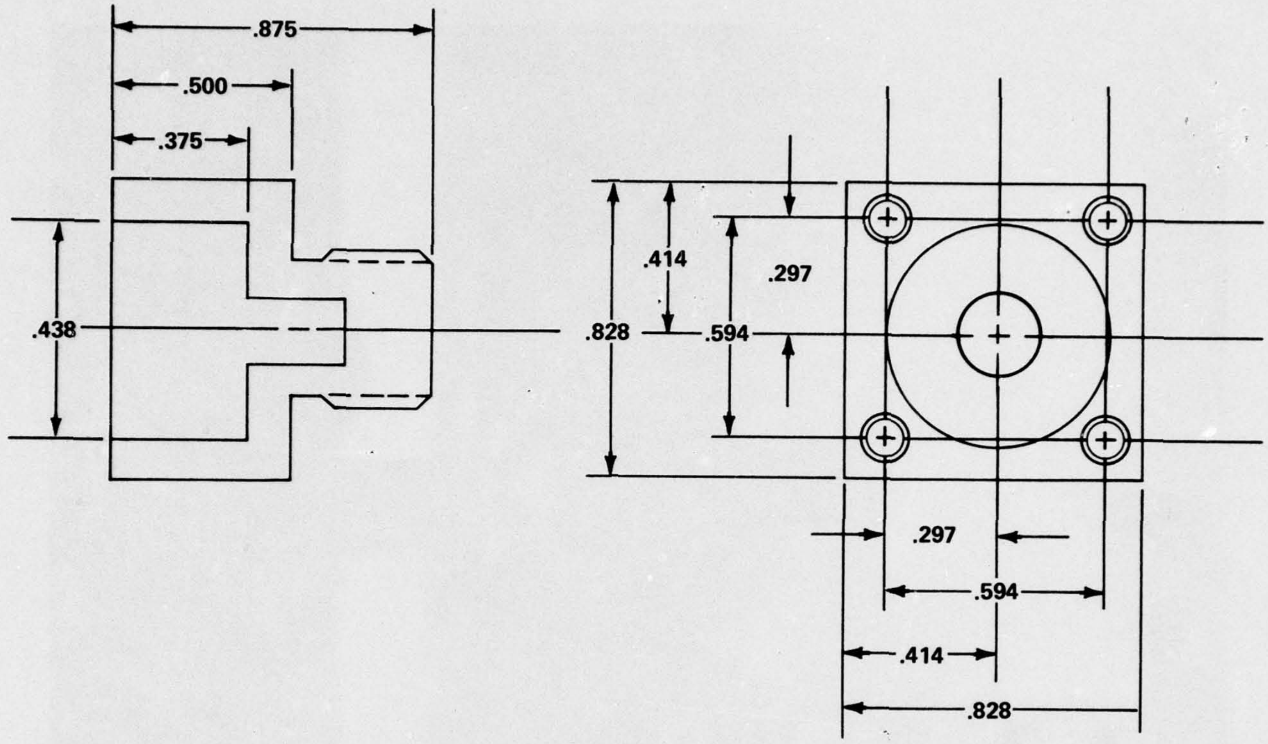
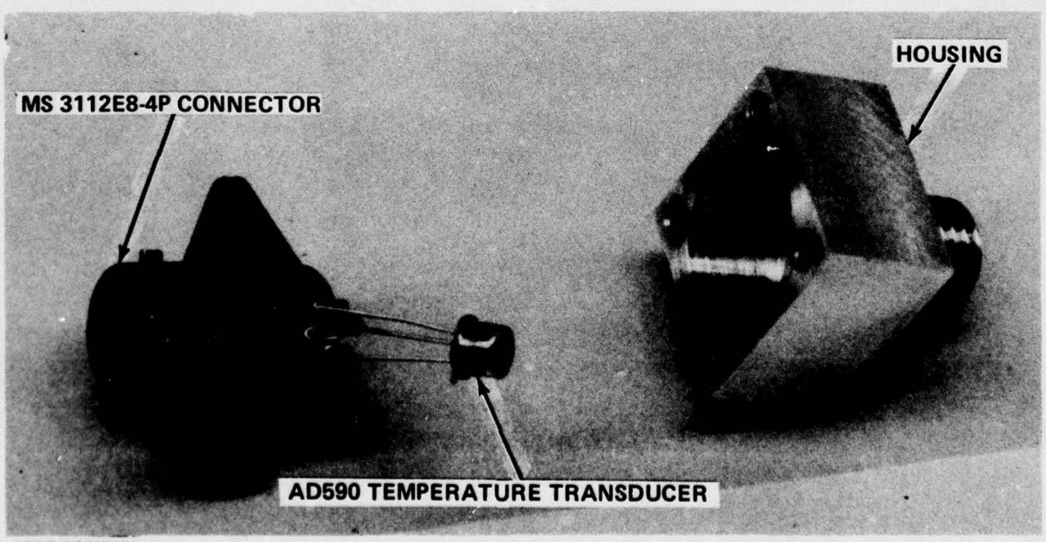


Figure 27. Calibration curve for an IC transducer.



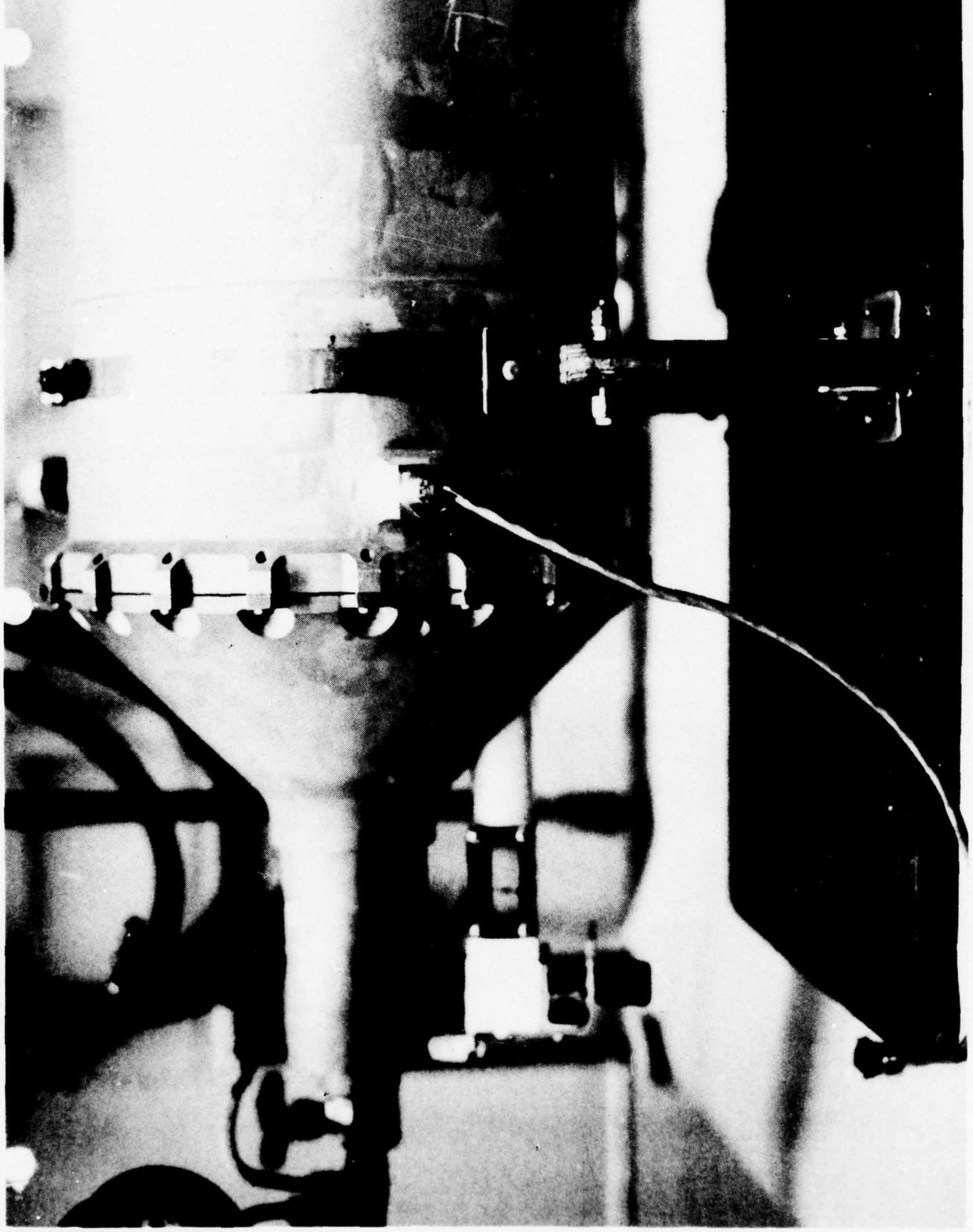
1087-031W

Figure 28. Temperature housing details.



1087-032W(1)

Figure 29. Temperature transducer assembly. (Sheet 1 of 2)



1087-032W(2)

Figure 29. Temperature transducer assembly. (Sheet 2 of 2)

2.2 HYDRAULIC FILTER MANIFOLD

The combined system hydraulic multiple-port filter manifold provides 5-micron absolute filtration to the pressure and return as well as the pump case drain line system. In addition, it contains:

- Main system relief valve
- Check valves
- Flow regulator
- Mechanical temperature indicator
- System pressure switch
- System pressure transmitter
- Filter differential pressure indicators.

The detailed assemblies are efficiently housed in a lightweight aluminum forging having eight standard port interfaces.

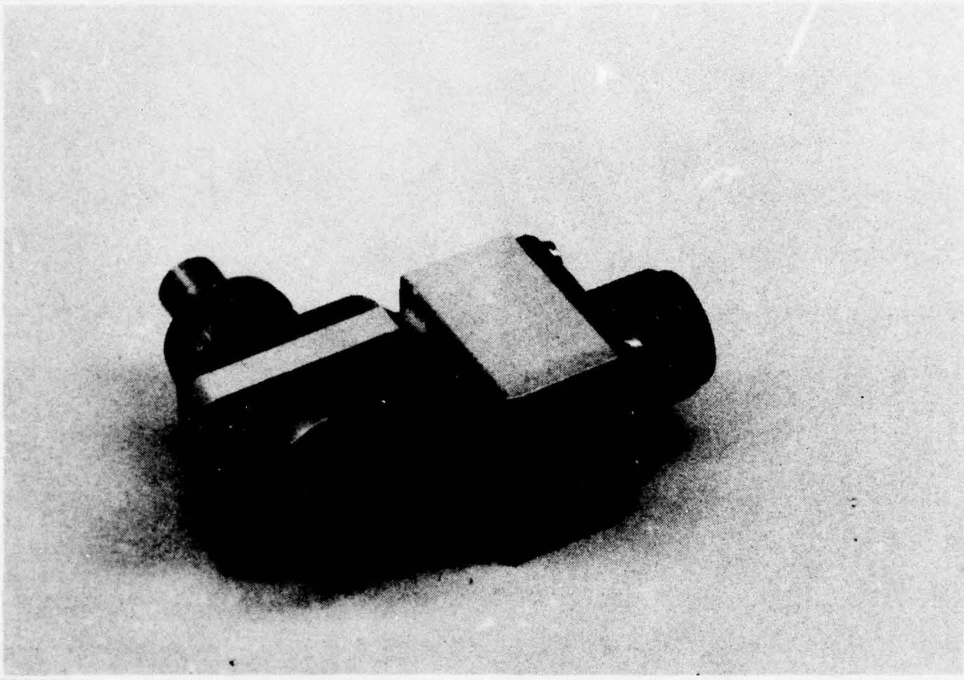
The filter manifold was modified by including an external temperature sensor (switch) adjacent to the modular relief valve. In addition, all production-type filter differential pressure indicators were replaced with APM deltadyne units. Figure 37 shows the installed units on the combined filter manifold.

2.2.1 Filter Differential Pressure Indicators

Filter differential pressure indicators, commonly used in the fluid power industry, are an indirect means of identifying contaminated filter elements which require servicing. The indicator is usually mounted to the filter head or bowl and provides a visual signal when a predetermined element differential pressure has been exceeded. In order to take into account fluid viscosity changes due to thermal conditions, various means are employed to preclude indicator operation before the system reaches normal operating temperature. One method uses a bimetallic sensing unit placed in close proximity to the visual indicator; another employs a temperature-sensitive gas, fluid, or elastomer.

To provide remote indication capability, an electrical switch may be mechanically or otherwise actuated by the primary sensor indicator. Resetting the mechanical indicator also resets the electrical circuit.

A boot or transparent cap is provided over the indicator to improve reliability by making it less susceptible to extrinsic debris and fluid. This cap is physically restrained or bonded to the adjacent element. Figure 30 shows one such unit.



1087-033W

Figure 30. Filter differential pressure indicator.

2.2.2 System Fluid Sampling

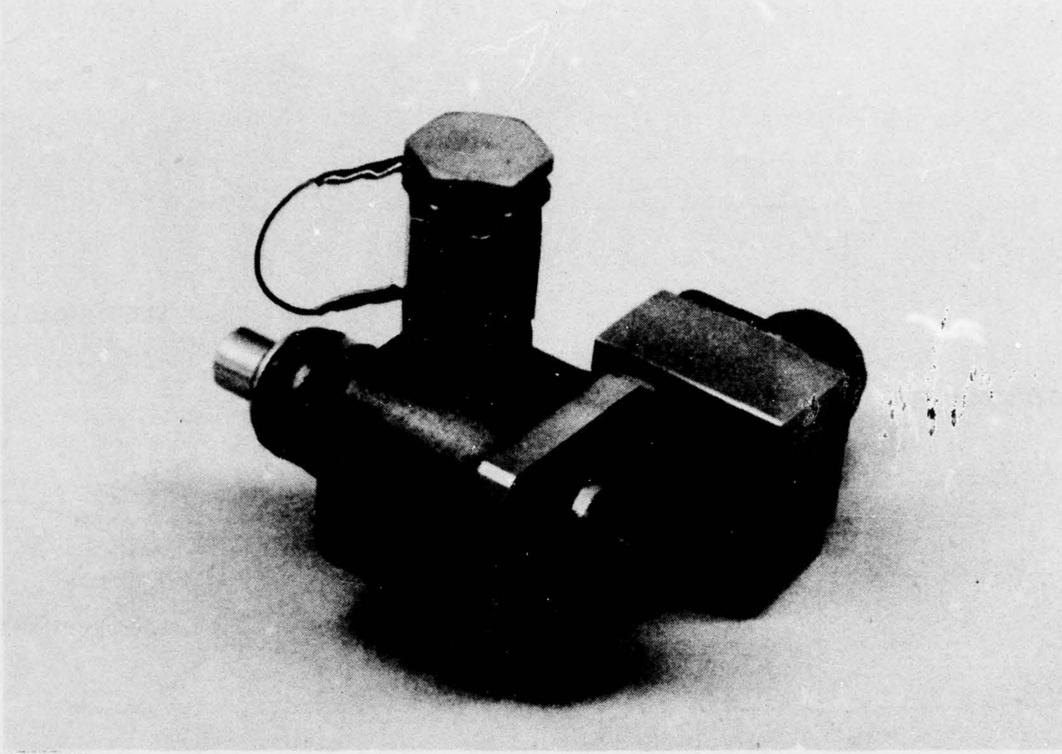
Another version of the delta-p indicator contains a sampling port which permits fluid extraction from the upstream side of the filter element while the system is pressurized. One such type of "Multicator"* is shown in Figure 31.

A special wired plug is used to protect the sampling port when not in use, and also acts as a redundant pressure seal.

Grumman Specification 202 defines the pertinent parameters of each unit used for the HYCOS Program.

It should be noted that most visual and electrical indicators are usually discrete signals (Go/No-Go type). In cases where an analog signal is required, this may be

* Multicator is an APM Trademark.



1087-034W

Figure 31. Filter differential pressure indicator with sampling valve.

provided by using the approach shown in Figure 32. This concept utilizes a linear output Hall Effect sensor actuated by a movable permanent magnet which is coupled to a spring-biased piston. Movement of the sensing piston magnet affects the magnetic flux density seen by the Hall Effect sensor, reducing the output signal. Since the sensor output varies as a function of ambient temperature, temperature compensation must be provided.

Figure 33 shows the Hall Effect sensor output as a function of air gap (Ref. 10) and the normalized sensitivity as a function of temperature. An operating temperature limitation of 32 °F to 158 °F precludes further consideration for type II hydraulic systems.

2.2.3 System Relief Valve

The combined system relief valve is part of the hydraulic filter manifold assembly (P/N AE-9416-21). The cartridge relief valve (P/N AC9347-41) assembly was modified to allow leakage across the seating land. Figure 34 shows the relief valve cartridge and manually resettable thermal switch used in the filter manifold assembly.

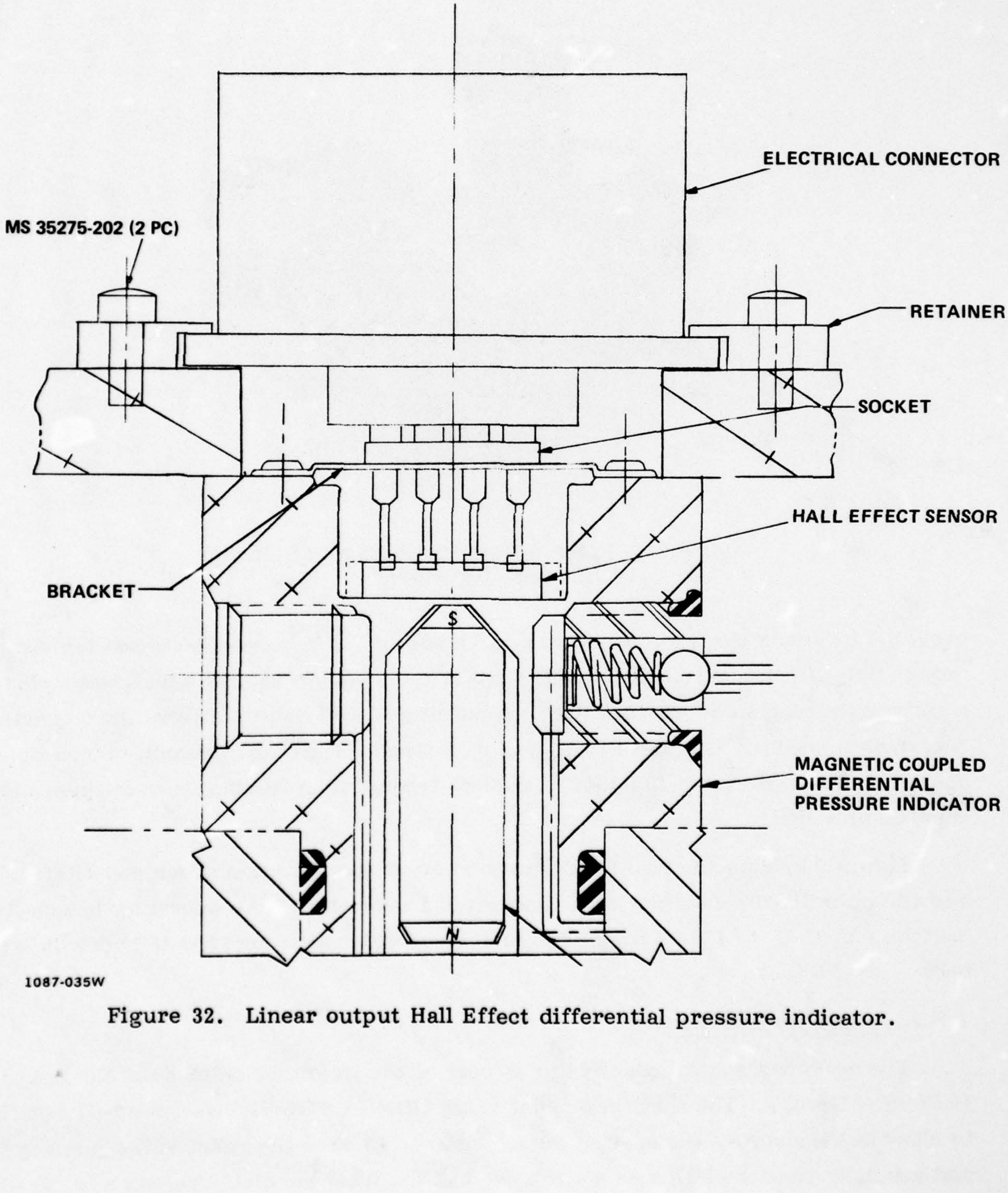
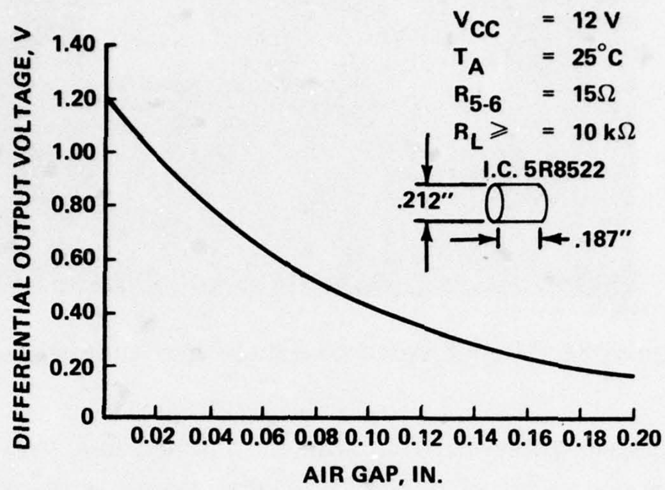
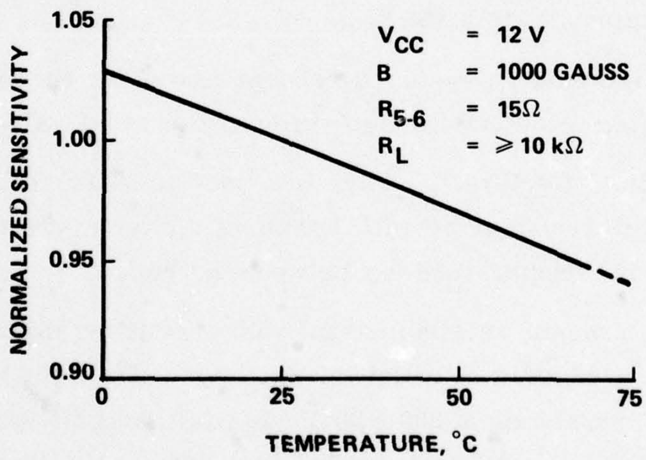


Figure 32. Linear output Hall Effect differential pressure indicator.



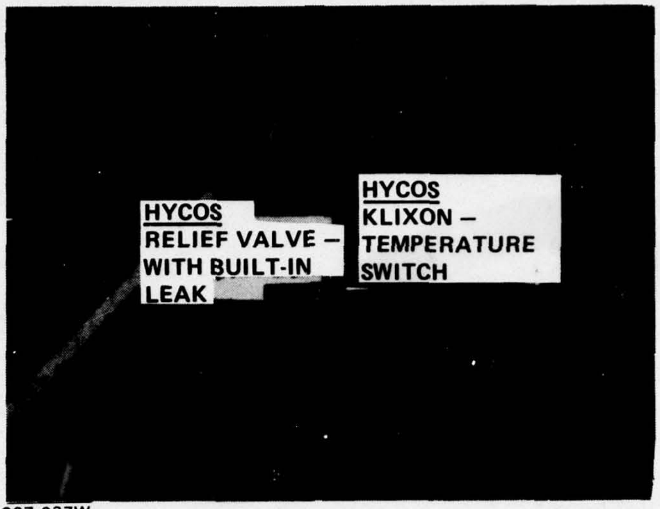
OUTPUT VOLTAGE
AS A FUNCTION OF AIR GAP



NORMALIZED SENSITIVITY AS A
FUNCTION OF TEMPERATURE

1087-036W

Figure 33. Differential pressure indicator curves.



1087-037W

Figure 34. Relief valve cartridge and thermal switch.

After initial system quiescent flow was established and system equilibrium temperatures determined, the modified relief valve was installed in the housing and temperature rise versus time data obtained (Figure 35). Under normal quiescent flow, temperature stabilized at approximately 126 °F. With the leaky relief valve in the system, stabilization occurred at approximately 186 °F.

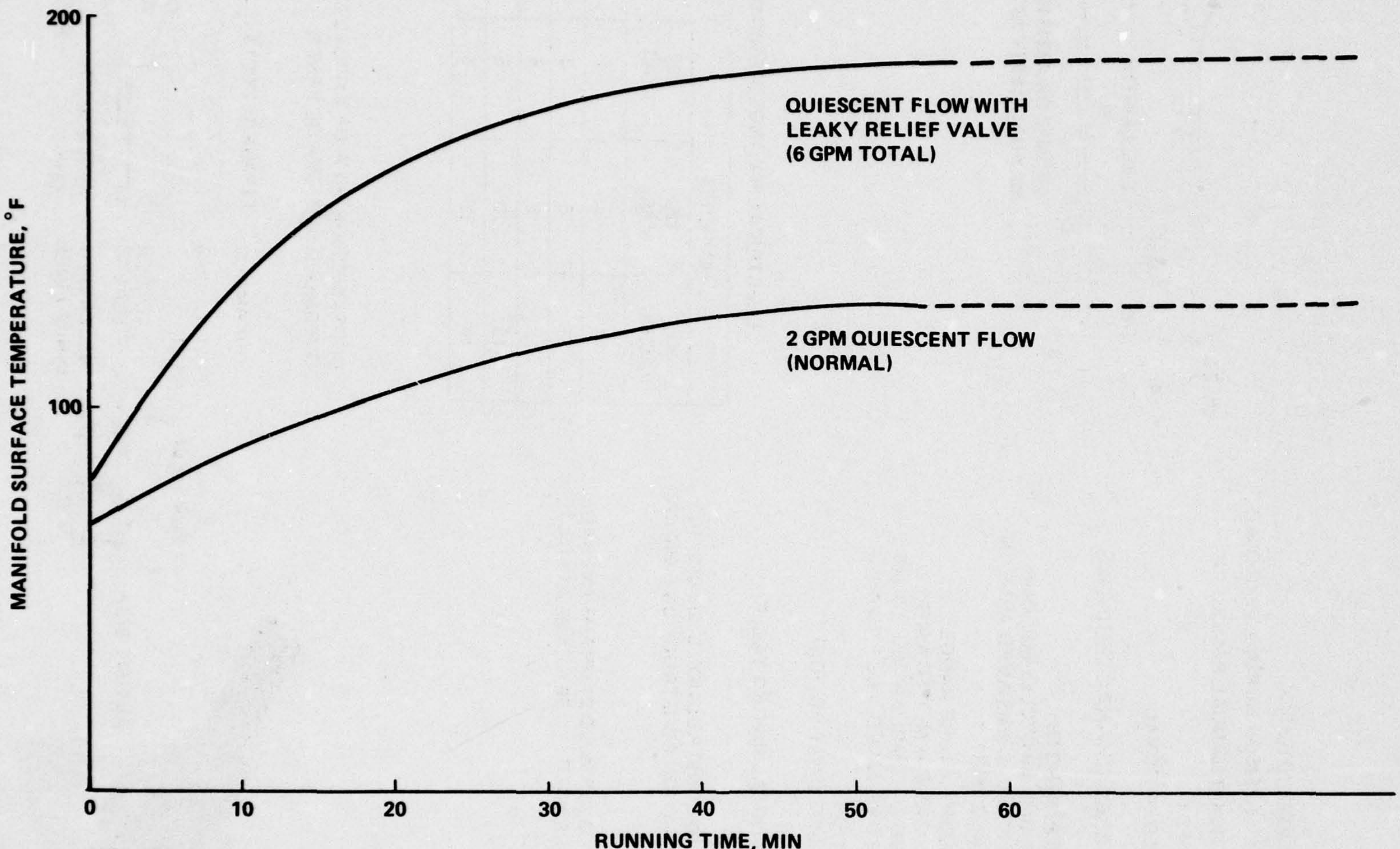
By noting the increase in system quiescent flow after the modified valve was installed, it was possible to detect leakage through the relief valve.

The filter manifold temperature gage was used to measure the increase in temperature at prescribed intervals, along with a contact surface-type thermocouple. Data obtained shows a 5-10° temperature lag between methods.

A surface-type manually resettable temperature switch conforming to Grumman Specification 201 was used to sense relief valve leakage. The switch is a Texas Instrument Klixon having a trip setting of 300 ± 20° F and reset manually with a neoprene overmold. Figure 36 shows a detailed photo of the temperature switch. Figure 37 shows the switch bonded to the hydraulic filter manifold.

2.2.4 Switch Operational Tests

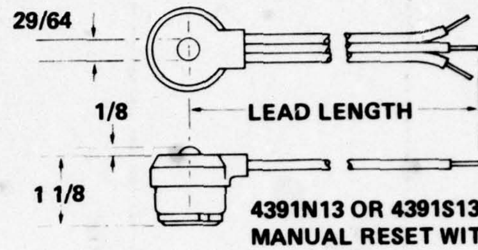
Prior to conducting system testing, the switch was tested in the mechanical test laboratory (Figure 38) using a hot plate as a variable heat source, a volt-ohmmeter to measure switch closure, and a digital display thermocouple circuit to measure hot-plate surface temperature. Increasing temperature caused the switch to trip at 304 °F;



1087-038W

Figure 35. Filter manifold surface temperature vs time using quiescent flow.

- SNAP-ACTION SWITCHING
- NORMALLY OPEN OR NORMALLY CLOSED
- AUTOMATIC OR MANUAL RESET
- SPST OR SPDT
- OVERMOLD OPTIONAL



4391N13 OR 4391S13 STYLE SPDT MANUAL RESET WITH OVERMOLD

PERFORMANCE CHARACTERISTICS

DIELECTRIC STRENGTH:
1250 VAC, RMS, 60 CYCLES FOR ONE MINUTE (1500 VAC RMS AVAILABLE ON SPECIAL REQUEST)

AMBIENT TEMPERATURE RANGE:
NON OVERMOLD – 65°F TO 450°F
NEOPRENE OVERMOLD – 65°F TO 160°F
SILICONE OVERMOLD – 65°F TO 450°F

SWITCH ACTION:
SPST OR SPDT (SNAP-ACTION)

LIFE CYCLE:
SEE ELECTRICAL RATING TABLE

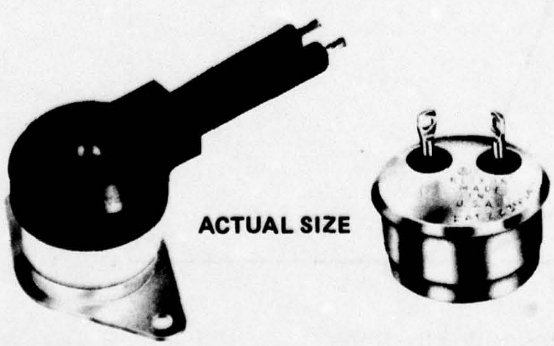
VIBRATION:
STANDARD CONSTRUCTION 5-500 CPS, 3G's
HIGH VIBRATION CONSTRUCTION 5-500 CPS, 5G's

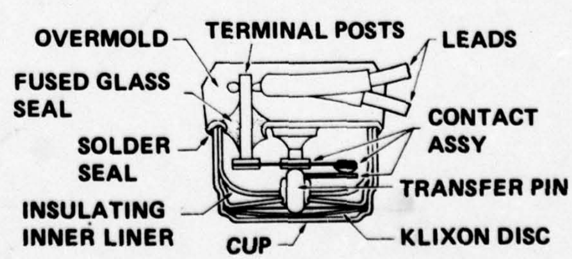
WEIGHT:
WITHOUT OVERMOLD 21 GRAMS AVERAGE
WITH OVERMOLD 56 GRAMS AVERAGE

ELECTRICAL RATINGS (RESISTIVE)

AMPERES			LIFE CYCLES
30 VAC/DC	125 VAC	250 VAC	
10	4	2	100,000
11	6	3	50,000
12	8	4	25,000
13	10	5	10,000
14	12	6	5,000

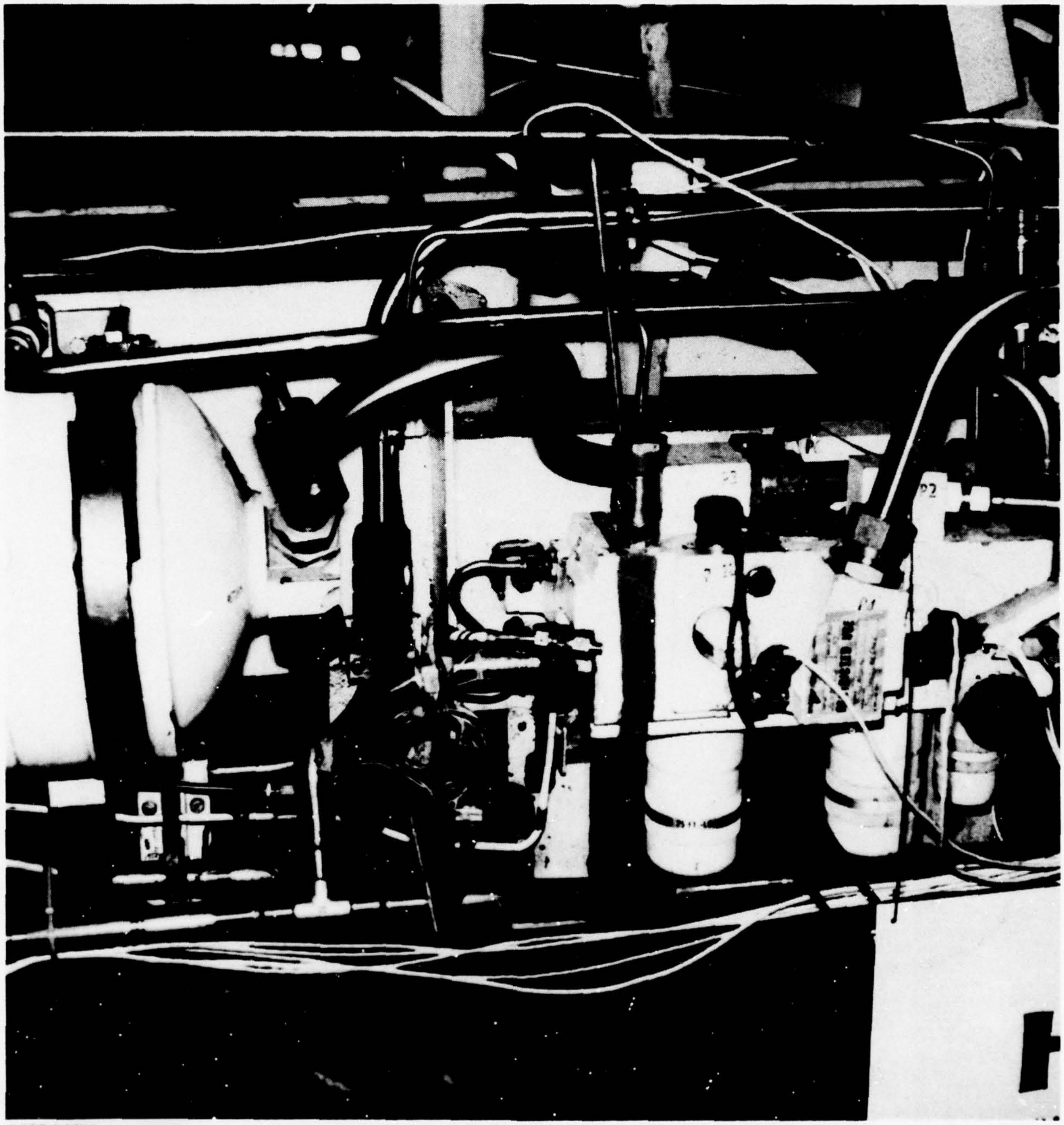
CROSS-SECTION VIEW OF TYPICAL UNIT WITH OVERMOLD (AUTOMATIC RESET)





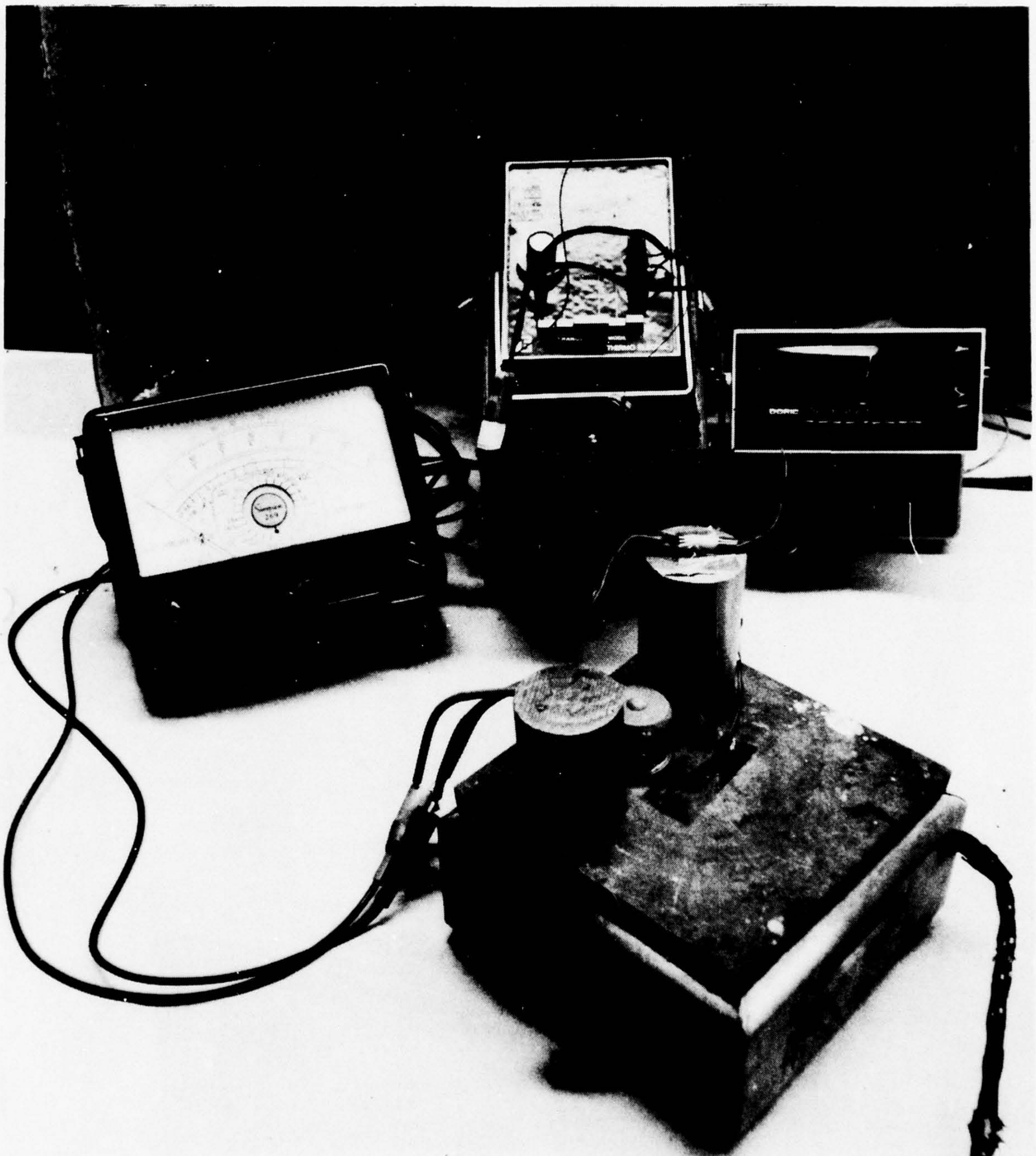
1087-039W

Figure 36. Resettable temperature switch.



1087-040W

Figure 37. Temperature switch on filter manifold.



1087-041W

Figure 38. Switch actuation tests.

this was repeated over several cycles. The plate was allowed to cool to room temperature, and switch indication did not change until manually reset.

2.2.5 Flight Control Backup Module

A Klixon overtemperature switch was mounted to the flight control backup module to measure system and closed-loop surface overtemperature conditions. This switch has the same trip settings as were used on the hydraulic filter manifold. Figure 39 shows the switch installation on the flight control backup module.

2.3 PNEUMATIC BOTTLES

Pneumatic bottles containing compressed gases may be categorized as energy storage devices and are used in numerous aircraft system applications. Some of the more common uses include:

- Hydraulic reservoir pressurization through the use of a pressure reducer
- Emergency escape systems by actuating a pyro device that initiates a sequence of events
- Emergency landing gear dump systems, assisting in gear lowering should an unlikely hydraulic system failure occur.

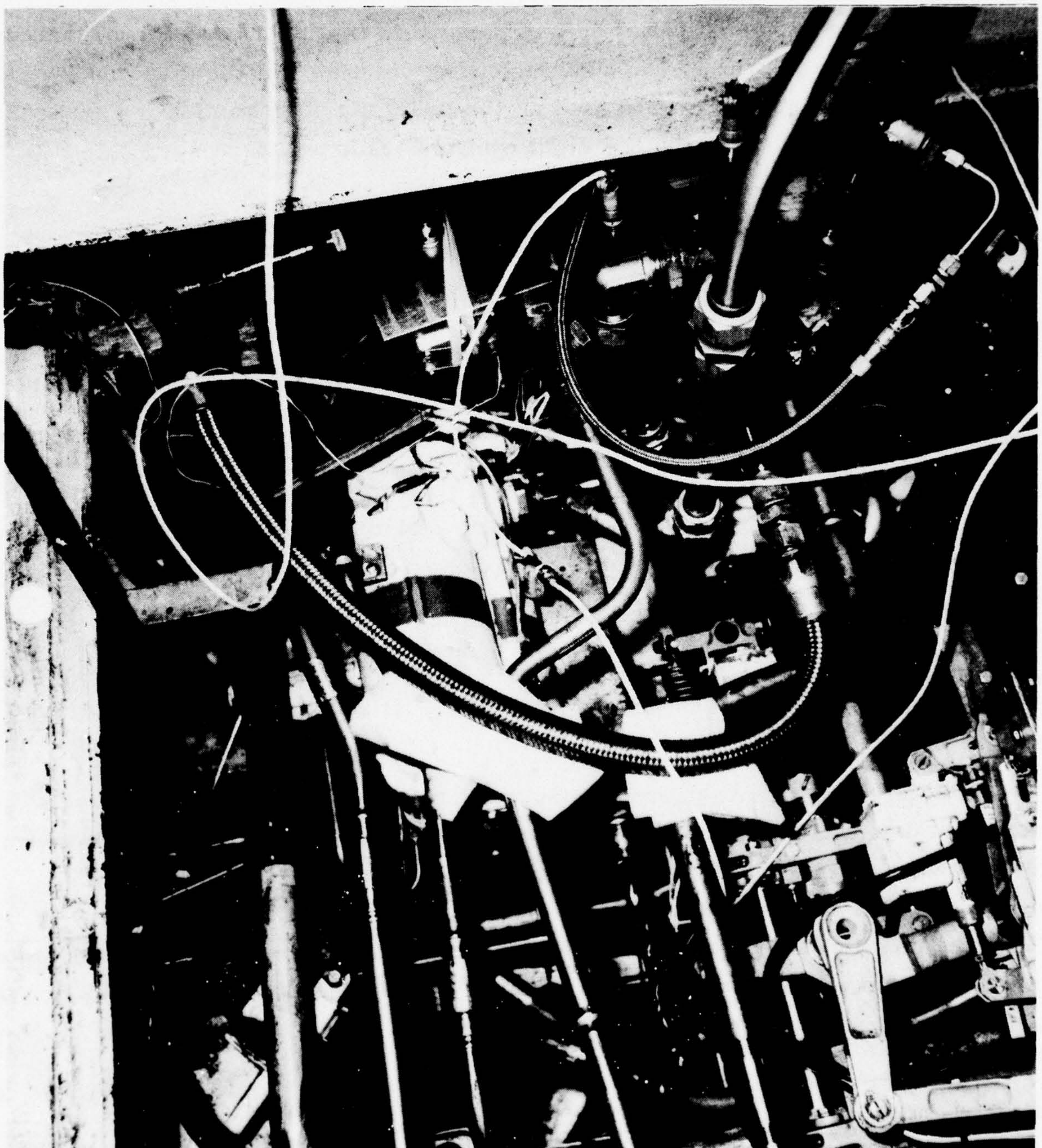
A typical special 210-day card is shown in Figure 40.

If the results of the procedure in Figure 40 are plotted on rectangular coordinates, we have the linear function shown in Figure 41. This relates to a slope (dp/dt) of 8.2 psi per °F.

In order to properly service the pneumatic bottle, the maintenance specialist must first obtain the ambient temperature and determine the corresponding pressure for that temperature. In addition, he must ascertain whether moisture or hydraulic oil inadvertently found its way into the pressurized container. NADC TR75169-30 (Page 39-42), Ref. 3, proposed the use of a temperature-compensated pressure switch in which the trip point changes as a function of gas temperature. In addition, the use of fiber optics for fluid detection in pneumatic bottles was also proposed (Ref. 3, Page 62-63).

2.3.1 Temperature-Compensated Pressure Switch

At the onset of the program, it became evident that no known pressure switch manufacturer had off-the-shelf hardware with built-in temperature compensation. One



1087-042W

Figure 39. Thermal switch mounted on flight control backup module.

CARD	TIME	RTG AMH NO.	MOS 6056 NO.			
81	00:20	1	1	SPECIAL 210 DAY	CANOPY/EMERGENCY GEAR NITROGEN BOTTLES	ELEC PWR OFF HYD PWR OFF

WORK AREA	WORK UNIT CODE SYS	WORK UNIT CODE SUB-SYS	CORR	TECHNICAL MANUAL NUMBER	CARD SET DATE	CHANGE NO.
				NAVAIR 01-F14AAA-6-3	15 January 1976	

GROUND SUPPORT EQUIPMENT REQUIRED

Trailer, Nitrogen 64A100H110

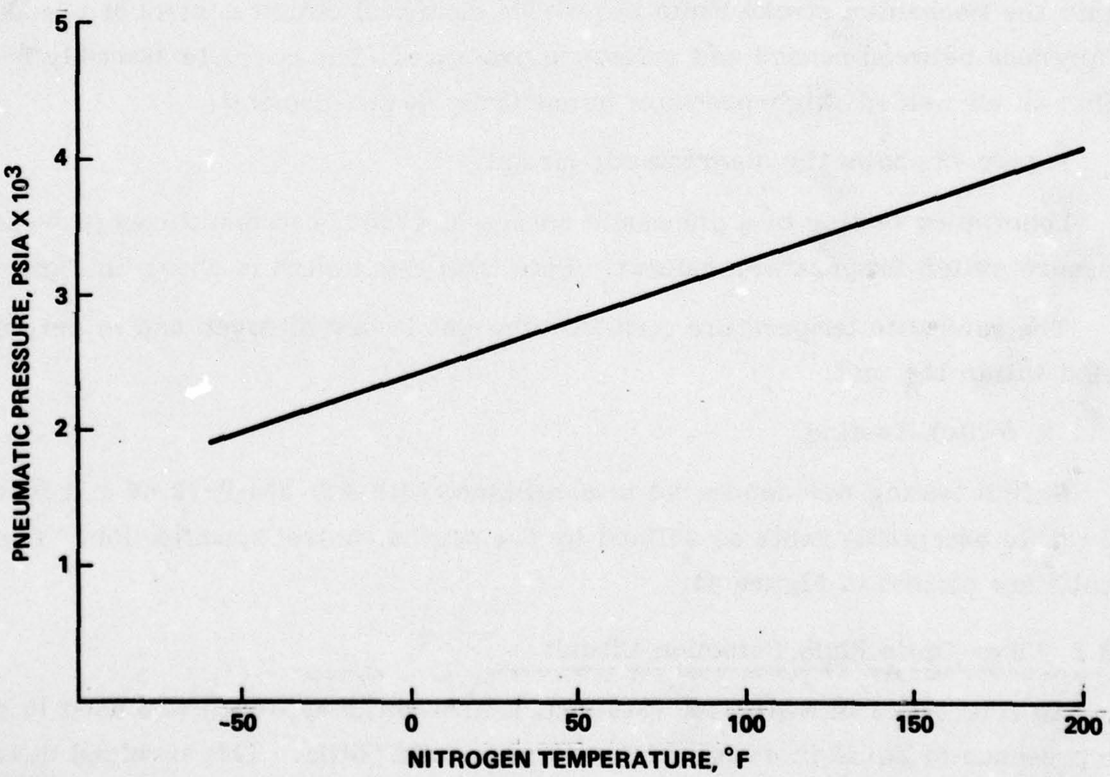
CONSUMABLES/REPLACEMENT PARTS

Nitrogen, Technical (Water-Pumped) BB-N-411B

WORK AREA	SYS	SUB-SYS	
15	13	712	1. Service canopy/emergency landing gear nitrogen bottles: a. remove cap from filler valve on pneumatic servicing module in nosewheel well. b. connect nitrogen supply to filler valve, then loosen locknut. c. slowly open nitrogen supply and pressurize nitrogen bottles to 3,000 psi. (Increase/decrease 3,000 psi by 82 psi for each 10°F increase/decrease from 70°F.) d. turn off nitrogen supply and tighten locknut on filler valve. e. disconnect nitrogen supply from filler valve and install cap.

1087-043W

Figure 40. Typical service card.



1087-044W

Figure 41. Plot of pressure vs temperature for nitrogen.

manufacturer, NeoDyn Incorporated of Chatsworth, California, was contracted to develop and build temperature-compensated pressure switches for the hydraulic monitoring system program. An initial Grumman sensor specification (Number 204) was prepared.

2.3.1.1 Switch Description

The switch is an all-welded, hermetically sealed unit which physically conforms to Figure 42. The switch senses applied pressure and compares it to an internal sealed self-contained reference pressure within the probe, which is at the same temperature as the sensed media. A proprietary, welded stainless-steel sensing diaphragm is exposed on one side to the probe reference pressure and on the other side to the sensed pressure. Pressure settings, which vary as a function of sensed and reference pressure, are accomplished through a force balance interaction between sensing diaphragm and a Belleville spring reference load. Since the reference pressure varies directly with sensed temperature, pressure settings are a function of temperature. Variation of reference pressure with temperature is shown graphically in Figure 41.

A precision snap-action electrical switch exposed to sensed pressure is positioned within the mechanism stroke limits to provide electrical circuit control at predetermined differences between sensed and reference pressure. The complete assembly is housed within an all-welded, high-pressure hermetically sealed housing.

Figure 43 shows the diagrammatic circuit.

Laboratory testing of a pneumatic charge at variable temperatures proved the pressure switch temperature concept. Data from this switch is shown in Figure 44.

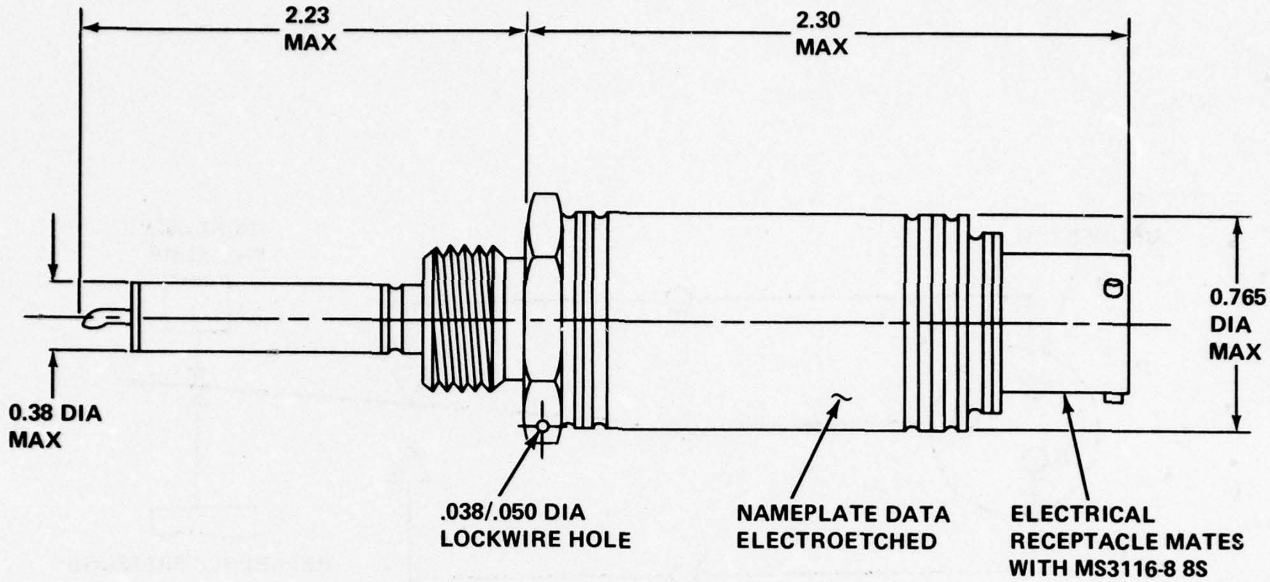
The reference temperature compensating gas is dry nitrogen and is hermetically sealed within the unit.

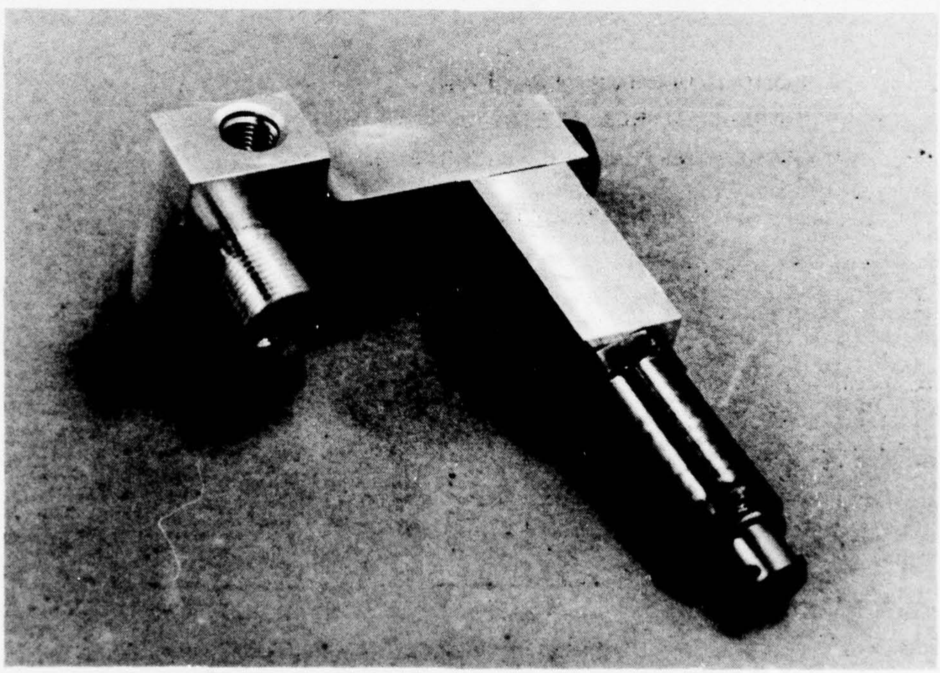
2.3.1.2 Switch Testing

Switch testing was conducted in accordance with A5I-314-P-72.48 and found to fall within acceptable limits as defined by the source control specification. The test results are plotted in Figure 44.

2.3.2 <u>Fiber-Optic Fluid Detection Circuit</u>

As referenced in NADC TR 75168-30, a fiber-optic approach was used to detect the presence of liquid in a high-pressure pneumatic bottle. This involved developing a method of liquid detection using optical properties of the gas, liquid, and transport





1087-045W

Figure 42. Temperature-compensated pressure switch.

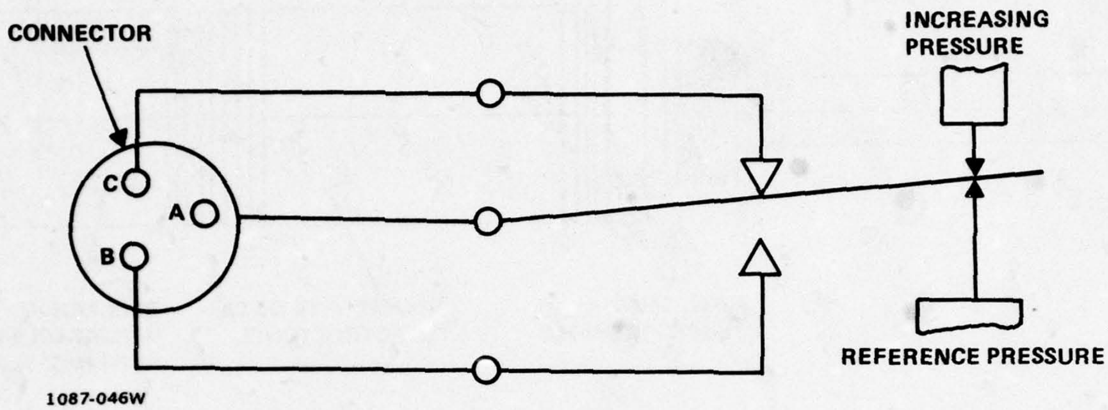


Figure 43. Temperature-compensated pressure switch: diagrammatic circuit.

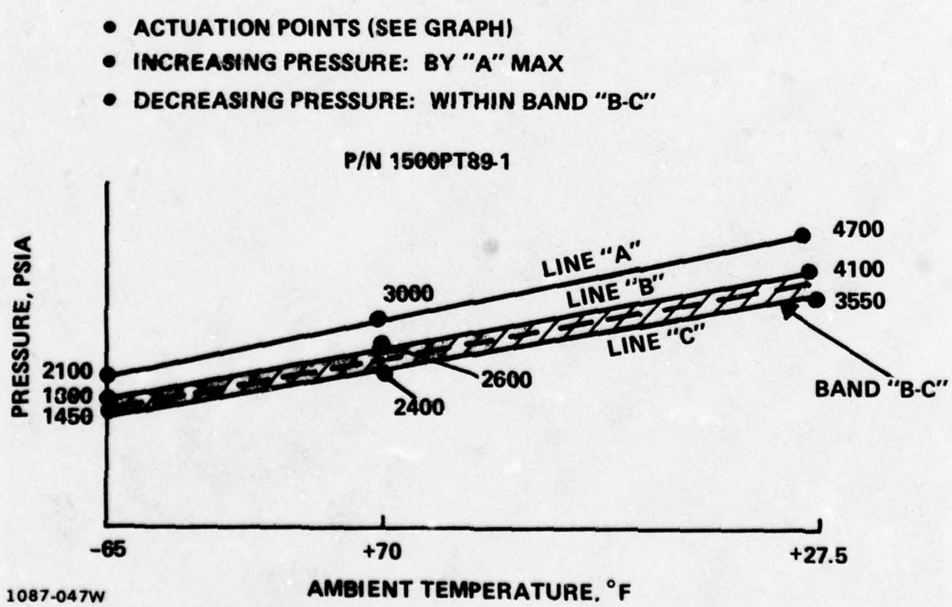


Figure 44. Switch actuation points vs temperature.

medium. In addition, methods of transporting the light source via a fiber-optics cable through a high-pressure seal became of paramount importance.

2.3.2.1 Liquid Detector

The liquid detector concept uses the optical properties of the light-conducting media. It is necessary to determine not only the properties of the light-conducting cables but also those of the fluids.

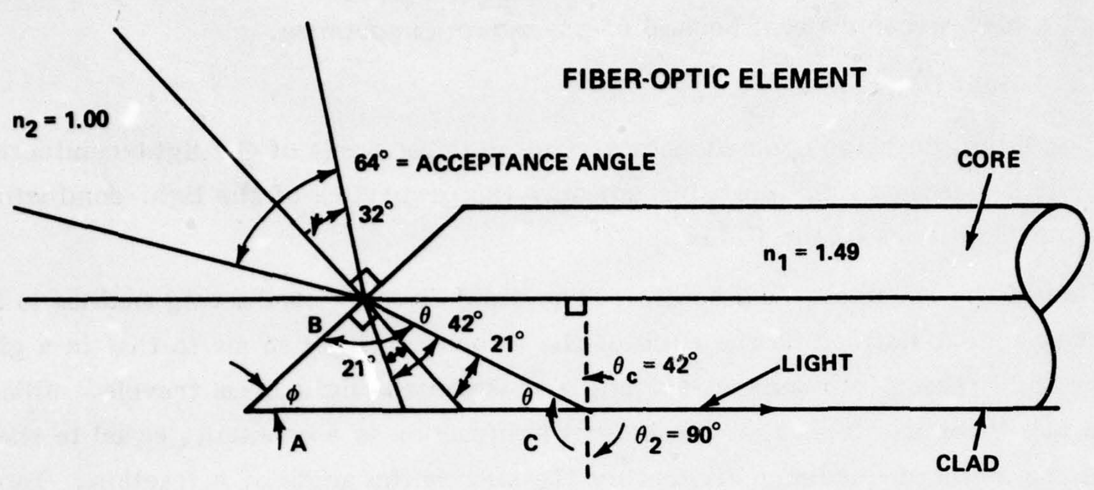
One of the important parameters of any fluid or light-conducting medium is its refractive index, defined as the ratio of the velocity of light in air to that in a given solid or fluid taking into account the angle at which the light beam travels. Willebrond Snell's Law of Sines states that the index of refraction is a constant, equal to the sine of the angle of incidence divided by the sine of the angle of refraction. Table 4 lists the refractive indices of various materials.

TABLE 4. REFRACTIVE INDICES OF VARIOUS ELEMENTS.

• WATER: 1.330	• MIL-H-83282 – 1.456
• AIR: 1.003	• MIL-H-6083 – 1.468
• MIL-H-5606: 1.463	
• CROFON (DUPONT)	• CABLE, FIBER-OPTIC TRANSMISSION
– CORE: 1.490	– CORE: 1.62
– CLAD: 1.392	– CLAD: 1.52
• LUCITE/PLEXIGLASS: 1.51	

1087-048W

During the course of development, it became apparent that a single large-diameter fiber would be used internally within the pneumatic bottle to detect the presence of a liquid, using the properties of the liquid for light coupling. The fiber angle in which a light ray would be lost when traveling through the conduit, unless the presence of water and/or hydraulic oil were available to permit optical coupling, was then derived mathematically. An analysis of the derivation follows:



1087-049W

$$\frac{\sin \theta_c}{\sin \theta_2} = \frac{n_2}{n_1}$$

$$\sin \theta_2 = \frac{n_1}{n_2} \sin \theta_c$$

$$\sin 90° = \frac{n_1}{n_2} \sin \theta_c$$

$$\frac{\sin 90°}{\sin \theta_c} = \frac{n_1}{n_2}$$

$$\frac{1}{\sin \theta_c} = \frac{1.49}{1.00}$$

$$\sin \theta_c = \frac{1.00}{1.49} \quad (1)$$

$$\theta_c = \sin^{-1} \frac{1.00}{1.49} = 42°$$

$\theta = 90° - \theta_c$ $\qquad \angle A = \phi$

$\angle B = 90° + 21°$

$\theta = 90° - 42°$ $\qquad \angle C = \theta$

$\theta = 48°$

$\Delta ABC = \theta + (90° + 21°) + \phi$

$180 = \theta + (90° + 21°) + \phi$

$180 = 48 + 90 + 21 + \phi$

$\phi = 21°$

Any beveled cut less than 21° will result in having light absorbed by the core.

Definitions

θ_c = critical angle

ϕ = angle required (beveled cut angle)

n = refractive index

θ = angle used in solving ϕ

Assume $n_2 = 1.33$ (index of refraction for water)

$$\sin \theta_c = \frac{1.33}{1.49} \quad (1)$$

$$\theta_c = \sin^{-1} \frac{1.33}{1.49} = 63°$$

Since θ_c (63°) exceeds the critical angle (42°), light will be transmitted through the light guide.

$$\theta = 90° - \theta_c$$
$$\theta = 90° - 63°$$
$$\theta = 27°$$

$$180° = \theta + (90° + 21°) + \phi$$
$$180° = 27° + 90° + 21° + \phi$$

$\phi = 42°$; beveled angle is increased, resulting in light being transmitted.

$$\sin \theta_c = \frac{1.4635}{1.49} \quad (2)$$

$$\theta_c = \sin^{-1} \frac{1.46}{1.49} = 79.2°$$

Since θ_c (79.2°) exceeds the critical angle (42°), light will be transmitted through light guide with a MIL-H-5606 coupling.

It has been shown in the laboratory that this approach works in the presence of either fluid. However, instead of using one multistrand fiber-optic cable it became necessary to employ two single-fiber cables with an external light source, with the flexible sensing probe at the bottom of the bottle. Figure 45 shows the concept of an early liquid sensor (Ref. dwg 1491901-307). This approach had screw-on terminals attached to the fiber-optic cables at both the sensing probe and a lucite conductor. The lucite conductor provided an optical means of passing light out of the pneumatic bottle while still retaining the pressure seal. This method proved unacceptable as losses through the fittings and connectors were so drastic that no detectable amount of light could be found at the output fiber. Modifications were made and all unnecessary connectors removed. The result was a design which had one continuous fiber carrying inputted light, a gap allowing fluid detection, and another continuous fiber carrying outputted light. This design (Figure 46) combined the sensor with the fiber-optic cables and greatly reduced transmission losses.

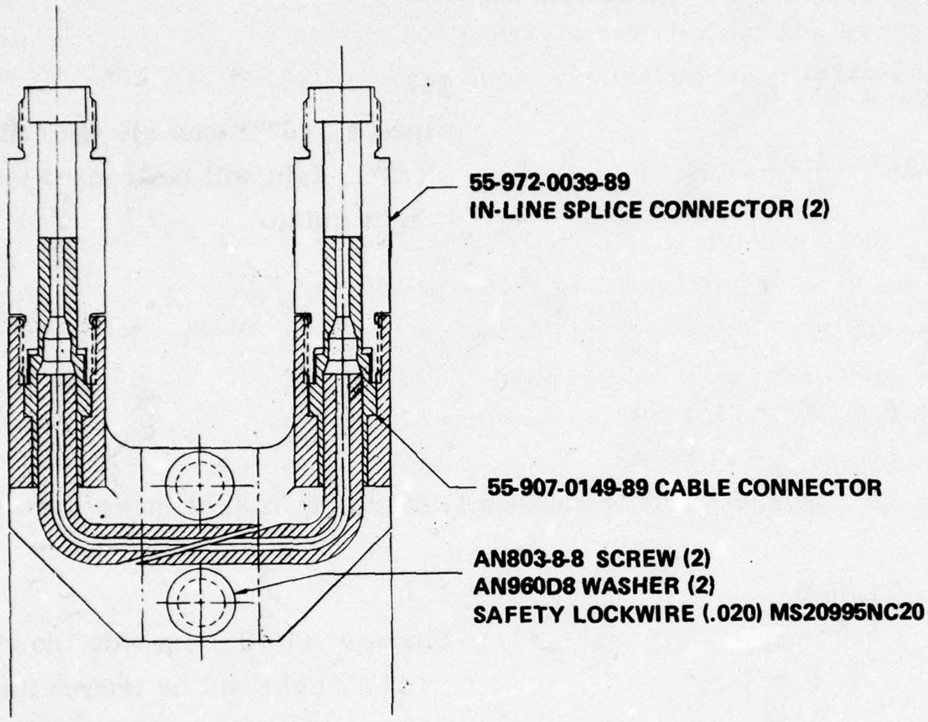


Figure 45. Liquid sensor assembly (early version).

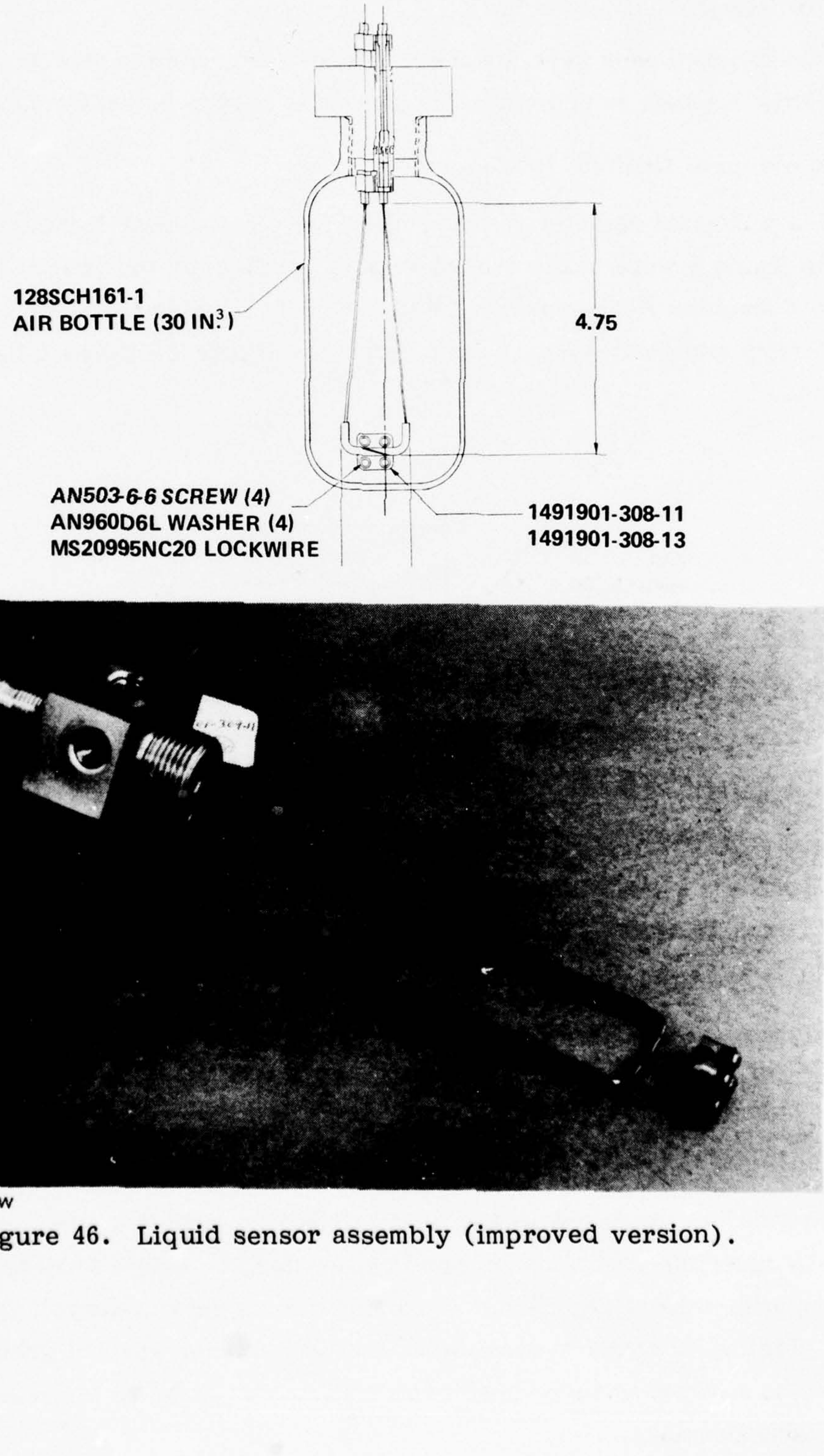
2.3.2.2 Fiber-Optic Cables

Two types of fiber-optic cables were purchased from Valtec Corporation, West Boylston, Massachusetts. The transmission cables were of the bifurcated and the single cable types. The bifuracted cable type is used on the pneumatic bottle detection loop, whereas the single cable is used on the desiccant color detection circuit.

Some of the parameters include:

- Number of fibers: 222-234
- Fiber diameter: 0.0031
- Bundle diameter: 0.045
- Acceptance cone angle: 68°
- Cone index of refraction: 1.62.

Additional cable information is provided in Appendix F, Specification No. 206. All cables use fiber-optic connectors in accordance with MIL-L-85044/1, developed by the Naval Ocean Systems Laboratory in San Diego, California. MIL-L-85044/1 covers



1087-051W

Figure 46. Liquid sensor assembly (improved version).

pressurized bulkhead connectors Type I class for relatively low-pressure systems. These stainless steel connectors were manufactured and supplied by the Sealectro Corporation in Mamaroneck, New York.

The cable terminal ends were installed in accordance with the procedure specified on Page 6 of MIL-C-85044; an epoxy bonding agent was used to fasten the assembly together.

2.3.2.3 Properties of Crofon Light Guides

Crofon is a Dupont registered trade name for plastic fiber light guides. The parameters in Table 5 were taken from a Dupont publication on Crofon Fiber Optics (Ref. 8) and a Machine Design article (Ref. 11). Table 5 shows some properties of the Crofon Fibers and their polyethylene jackets. Figure 47 shows a light ray entering the light guide.

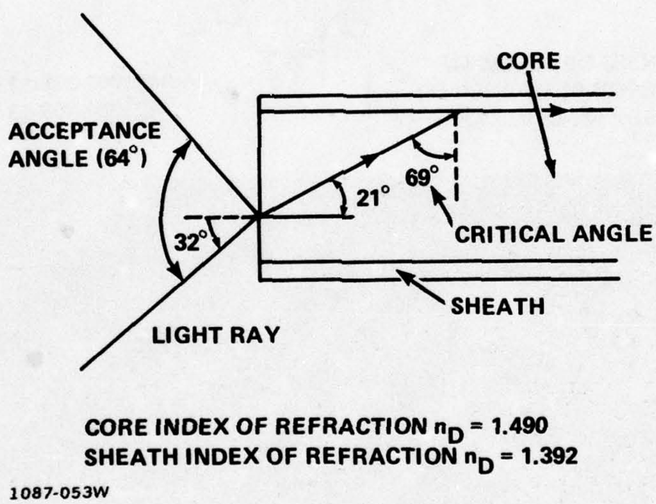


Figure 47. Crofon light guide properties.

Transmission of light through Crofon varies as a function of length. It is also dependent on input light intensity, output light interfaces, and any gap through the optic circuit. Figure 48 shows the transmission efficiency of white light through carefully polished light guides.

Single bends are employed in the liquid detection circuit at the sensor end. It is desirable to ascertain the minimum bend radius for the single 1056 light guide. Too severe a bend will cause a significant light loss due to degradation of the cladding and fiber itself. Figure 49 shows typical light transmission for several grades of Crofon light guides. It becomes evident that bend radius should be as large as possible to minimize transmission loss.

TABLE 5. PROPERTIES OF CROFON FIBERS WITH POLYETHYLENE JACKETS.

A. IDENTIFICATION: CROFON 1056

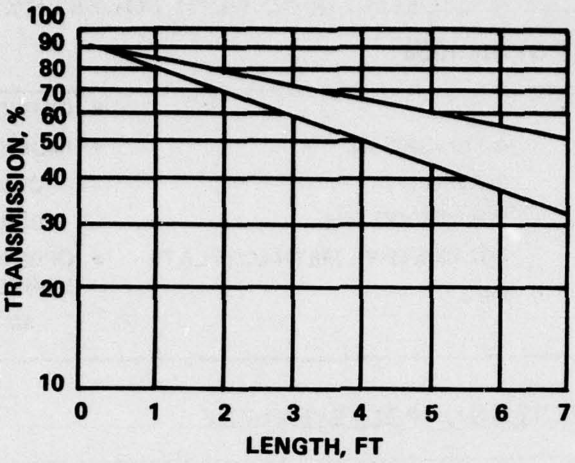
- NUMBER OF FIBERS: 1
- OD: 0.111 ±.005 IN.
- FIBER DIAMETER: 0.056 IN.
- JACKET MATERIAL: POLYETHYLENE
- FIBER: POLYMETHYL METHACRYLATE
- ACCEPTANCE ANGLE: 64°
- CRITICAL ANGLE: 69°
- INDEX OF REFRACTION:
  - CORE N_D = 1.490
  - CLAD N_D = 1.392
- OPERATING TEMPERATURE LIMITS:
  -40 °F TO 175 °F

B. TYPICAL PROPERTIES OF POLYETHYLENE

ASTM TEST	PROPERTY	LOW DENSITY	MEDIUM DENSITY	HIGH DENSITY	ULTRAHIGH MOLECULAR WEIGHT
	PHYSICAL				
D792	SPECIFIC GRAVITY	0.910-0.925	0.926-0.940	0.941-0.965	0.928-0.941
–	SPECIFIC VOLUME (IN.^{3}/LB)	30.4-29.9	29.9-29.4	29.4-28.7	29.4
D570	WATER ABSORPTION, 24 HR, 1/8-IN. THK (%)	<0.01	<0.01	<0.01	<0.01
	MECHANICAL				
D638	TENSILE STRENGTH (PSI)	600-2,300	1,200-3,500	3,100-5,500	4,000-6,000
D638	ELONGATION (%)	90-800	50-600	20-1,000	200-500
D638	TENSILE MODULUS (10^5 PSI)	0.14-0.38	0.25-0.55	0.6 - 1.8	0.20-1.10
D785	HARDNESS, ROCKWELL R	10	15	65	55
D790	FLEXURAL MODULUS (10^5 PSI)	0.08-0.60	0.60-1.15	1.0-2.0	1.0-1.7
D256	IMPACT STRENGTH, IZOD (FT-LB/IN. OF NOTCH)	NO BREAK	0.5-16	0.5-20	NO BREAK
	THERMAL				
C177	THERMAL CONDUCTIVITY (10^{-4} CAL-CM/SEC-CM^2-°C)	8.0	8.0-10.0	11.0-12.4	11.0
D696	COEF OF THERMAL EXPANSION (10^{-5} IN./IN. - °C)	10-22	14-16	11-13	14
D648	DEFLECTION TEMPERATURE (°F)				
	AT 264 PSI	90-105	105-120	110-130	118
	AT 66 PSI	100-121	120-165	140-190	170
–	CONTINUOUS, NO-LOAD SERVICE TEMP (°F)	180-212	220-250	250	–
	ELECTRICAL				
D149	DIELECTRIC STRENGTH (V/MIL) SHORT TIME, 1/8-IN. THK	460-700	460-650	450-500	900*
D150	DIELECTRIC CONSTANT				
	AT 60 Hz	2.25-2.35	2.25-2.35	2.25-2.35	–
	AT 10^3 Hz	2.25-2.35	2.25-2.35	2.30-2.35	2.30-2.35
D150	DISSIPATION FACTOR AT 10^3 Hz	0.0002	0.0002	0.0003	0.0002
D257	VOLUME RESISTIVITY (OHM-CM) AT 73°F, 50% RH	10^{15}	10^{15}	10^{15}	10^{15}
D495	ARC RESISTANCE (SEC)	135-160	200-235	–	–
	OPTICAL				
D542	REFRACTIVE INDEX	1.51	1.52	1.54	–
D1003	TRANSMITTANCE (%)	4-50	4-50	10-50	–

*kV/CM

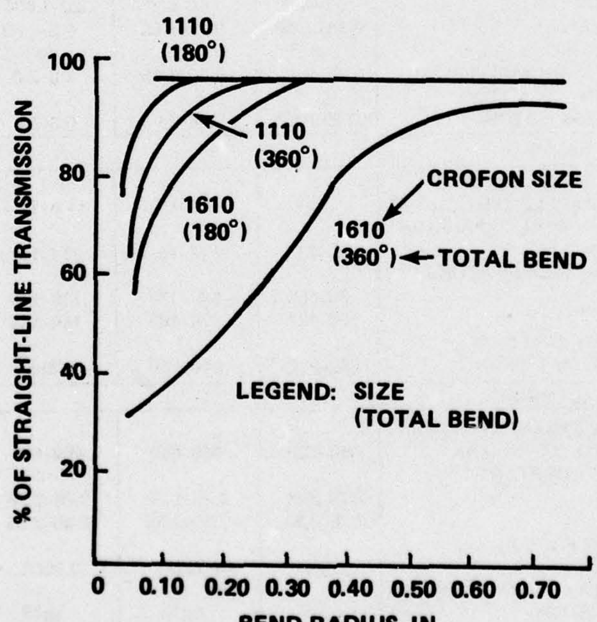
1087-052W



NOTE: TRANSMISSION VALUES ARE FOR LIGHT GUIDES WITH CAREFULLY POLISHED ENDS.

1087-054W

Figure 48. Transmissivity of Crofon light guides.



1087-055W

Figure 49. Effect of bend radius on light transmissivity.

2.3.2.4 Fiber-Optic Connectors

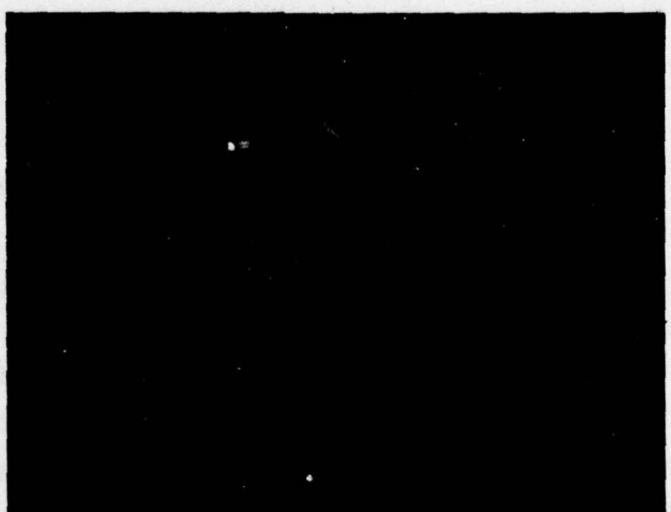
Numerous types of fiber-optic connectors were considered for use in HYCOS. The major concern was the availability of a high-pressure bulkhead fitting capable of sealing 3000 psi pneumatic pressure. As of February 1978, no bulkhead connectors on the market were capable of withstanding this high pneumatic pressure differential without leakage.

Contact was established with Robert Lebduska and D. Ben Forman of the Naval Ocean Systems Center (271 Catalina Boulevard, San Diego, California 92152) through Dick Bradshaw (Grumman EED Group). Grumman was informed that the proposed MIL-C-85044/1 Connector, Fiber-Optic, Pressurized Bulkhead, Type I, Class I was being manufactured by Sealectro Corporation, Mamaroneck, New York. Sealectro indicated that the connectors were in stock.

Sealectro part numbers are:

- Cable Connector: 55-907-0149-89
- In-Line Splice: 55-972-0039-89
- Bulkhead Mounting Connector: 55-975-0049-89

All parts are made of corrosion-resistant stainless steel. Figure 50 shows a typical fiber-optic terminal used in HYCOS. The weight of fiber-optic cable-elements are as tabulated below:



1087-056W

Figure 50. Fiber-optic assembled connector.

- Cable Connector . . . . 0.1056 Oz
- In-Line Splice . . . . 0.1764 Oz
- Bulkhead Fitting . . . . 0.3527 Oz

The connector has a fiber terminal diameter of 0.0465 in. (area = 0.001698 $in.^2$). For HYCOS, special connector interfaces were designed to withstand the intended environment.

The fiber-optic termination procedure (Figure 51) as defined in MIL-C-85044/1 follows:

1. Roughen the surface of the jacket with sandpaper 1-1/2 in. from the end of the cable. Make sure that deep grooves are placed in the jacket. This assures a good epoxy bond.
2. Strip 1 in. of jacket off the cable using a #16 hole in standard wire strippers.
3. Dip the exposed glass fibers in alcohol to pull the fibers together. Wipe off excess. Do not get the jacket wet. There should be 1 in. exposed glass fibers on the end of the cable.
4. Carefully slip the terminal onto the glass fibers to the edge of the jacket. If the glass is hanging up within the terminal, the fibers will blow-out. Rotating the terminal should eliminate this problem. Heat the terminal and fibers with a heat gun to dry the alcohol.
5. Apply epoxy to the roughened jacket. Slide the terminal over the jacket and wipe off the excess epoxy.
6. Cut the fibers, leaving 1/4 in. of exposed fibers extending beyond the terminal.
7. Apply epoxy to the exposed fibers. Work the epoxy into the fibers to eliminate air bubbles.
8. Heat the exposed glass fibers with a heat gun to cure the epoxy. The epoxy will turn a dark red when cured. Gradually apply the heat down the length of the terminal. Be sure to cure the epoxy at the jacket-terminal interface. The cable should be held horizontal to prevent epoxy from dripping down the cable. It is easier to see the epoxy turn red if a small amount of epoxy is put on the terminal at the jacket-terminal junction. Care must be taken not to overheat the jacket. The maximum jacket temperature should not be exceeded (150 °C

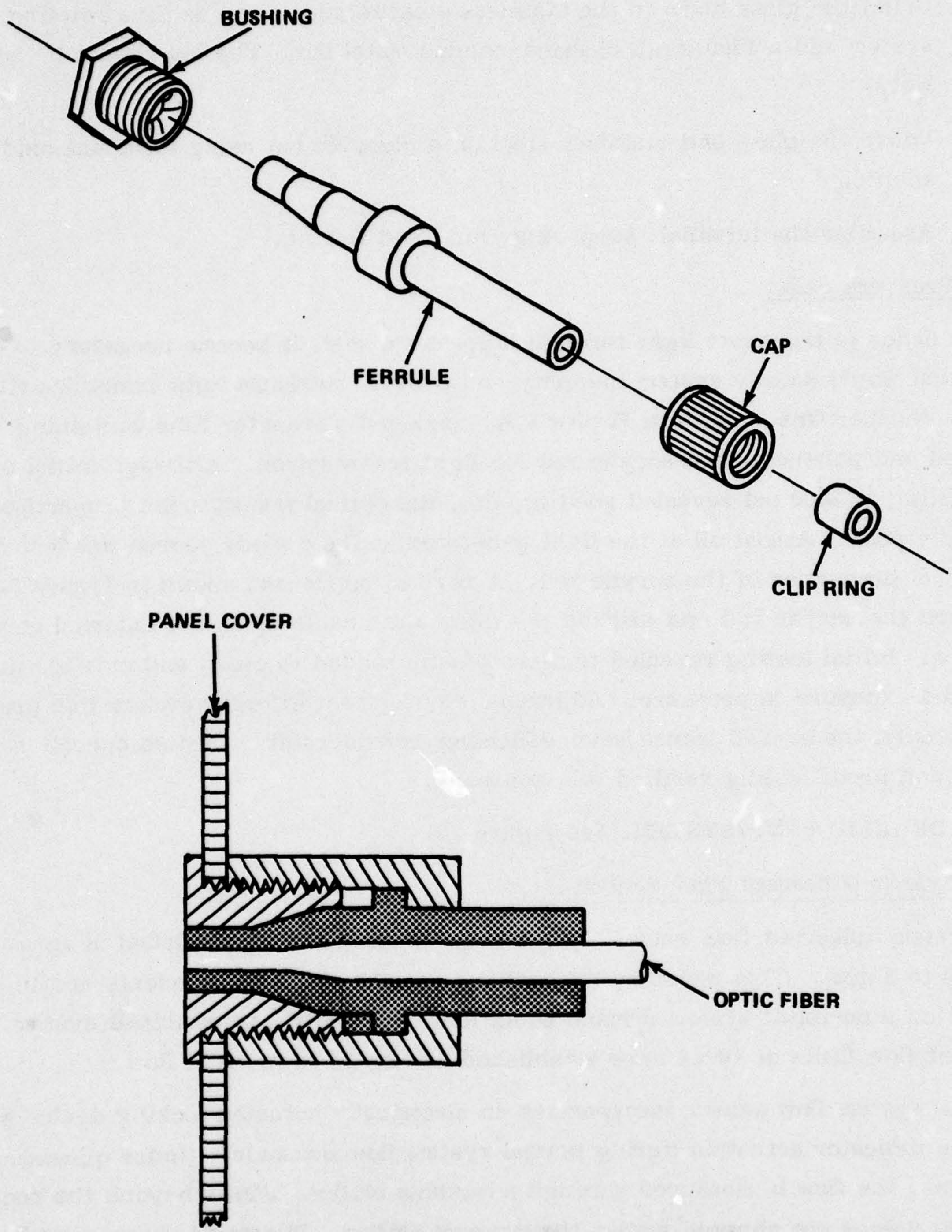


Figure 51. Display panel fiber-optic termination.

for Hytrel). A temperature check of the heat gun is recommended.

9. Grind the glass down to the stainless steel terminal face using a rotating lap system and a 1500-mesh diamond-bonded metal lap. The lap should be run wet.

10. Polish the glass and stainless steel on a phenolic lap using aluminum oxide in solution.

11. Assemble the terminal, snap-ring, nut, and O-ring.

2.3.3 Pressure Seal

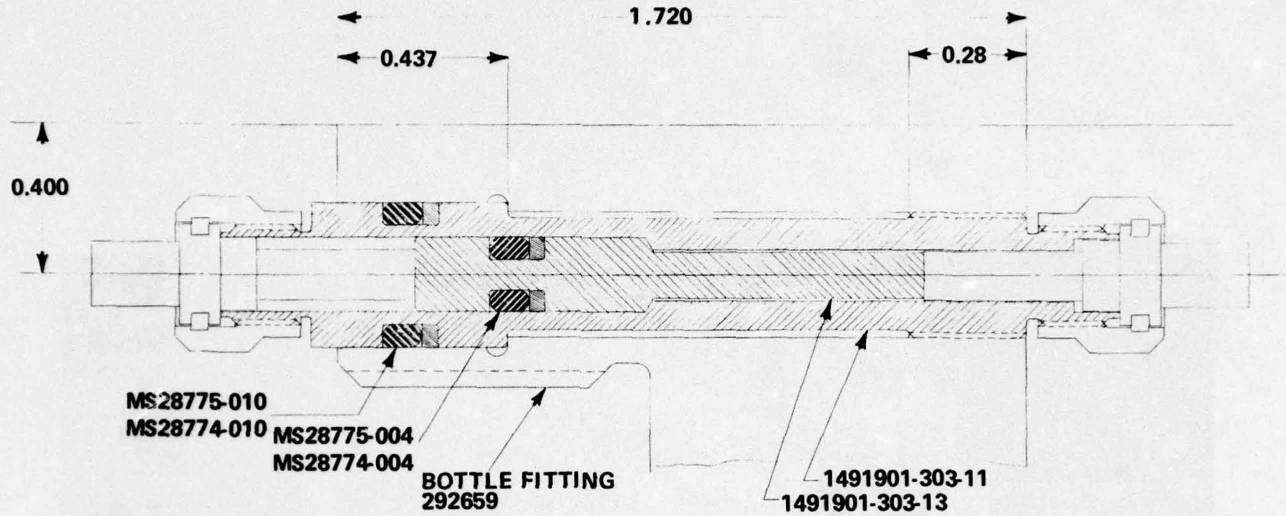
In order to transport light through a pressure seal, it became necessary to design a seal that would satisfy system integrity and provide maximum light transmissivity. Concept Number One, shown in Figure 52A, employed a transfer tube containing a machined and polished clean acrylic rod for light transmission. Although initial pressure testing at 3000 psi revealed good results, the optical transmission properties were very poor. Almost all of the light generated at the outside source was lost due to the optical properties of the acrylic rod. A revised approach, shown in Figure 52B, eliminated the acrylic rod and *utilized the fiber-optic cable up to the external connector* interface. Initial testing revealed that the plastic tended to creep and extrude under prolonged exposure to pressure. Additional development effort overcame this problem and improved the overall transmission efficiency considerably. Limited operational cycling and proof testing verified this approach.

2.4 HYDRAULIC PUMP/SYSTEM (See Figure 53)

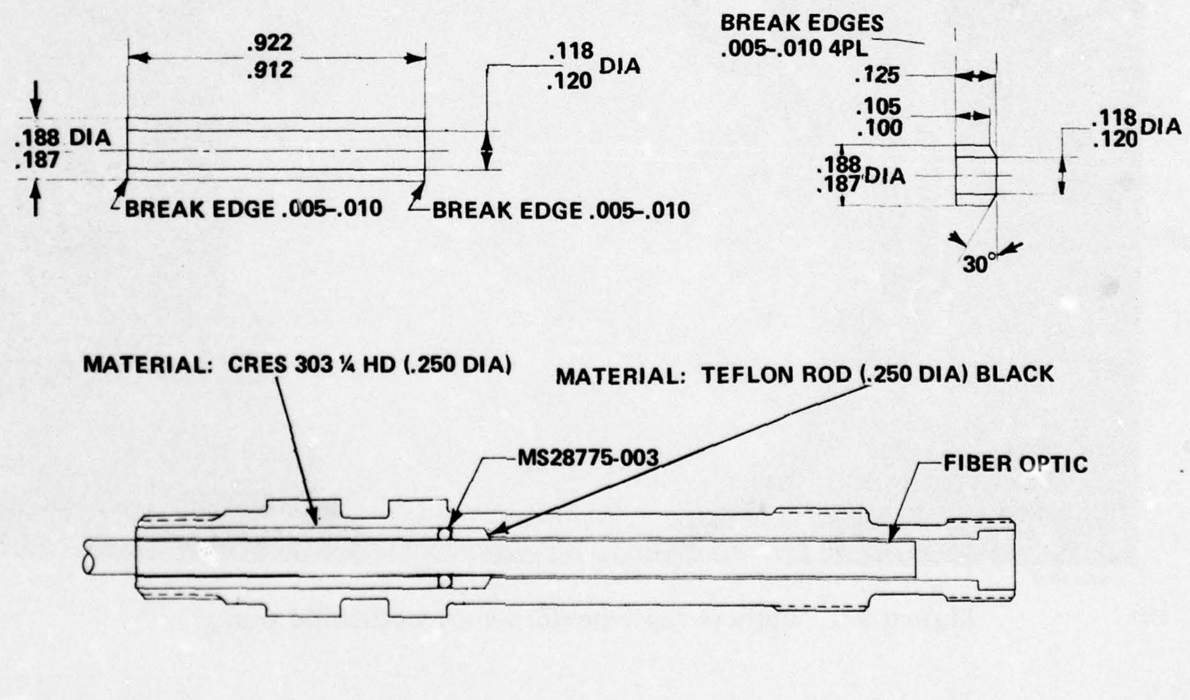
2.4.1 System Quiescent Flow Sensor

System quiescent flow values for the F-14A system were established at approximately 4 to 5 gpm. This will vary depending on which system components are on the line during a no-input system demand condition. For the F-14A combined system, quiescent flow limits of 10-14 were established as excessive internal flow.

The system flow sensor incorporates an electrically actuated locking device which prevents indicator actuation during normal system flow demands. Under quiescent flow conditions, the flow is measured through a movable orifice. Flows beyond the required measured values are shunted across the movable orifice. Figure 54 shows a typical quiescent flowmeter used in the simulator testing program.



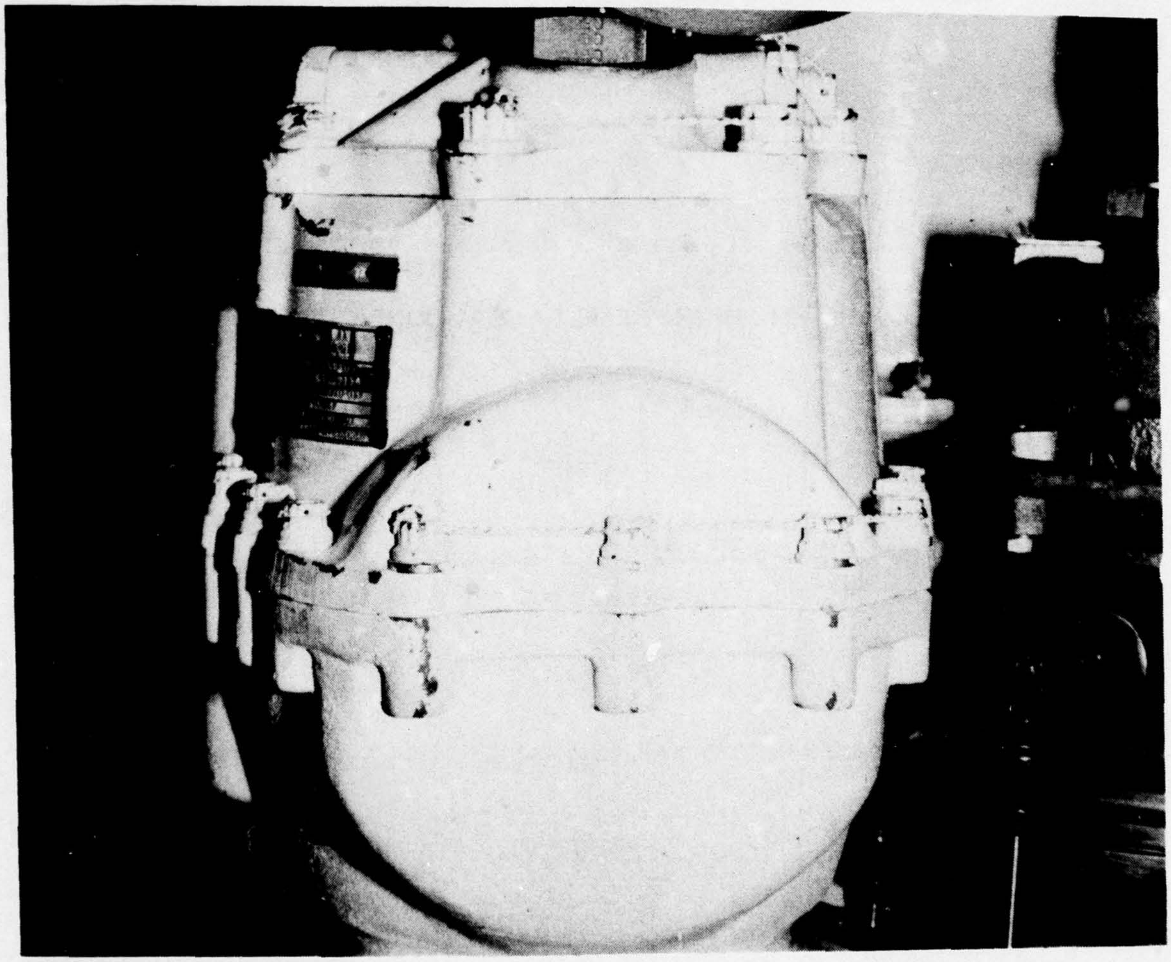
A. PNEUMATIC HIGH-PRESSURE SEAL CONFIGURATION



B. IMPROVED HIGH-PRESSURE SEAL

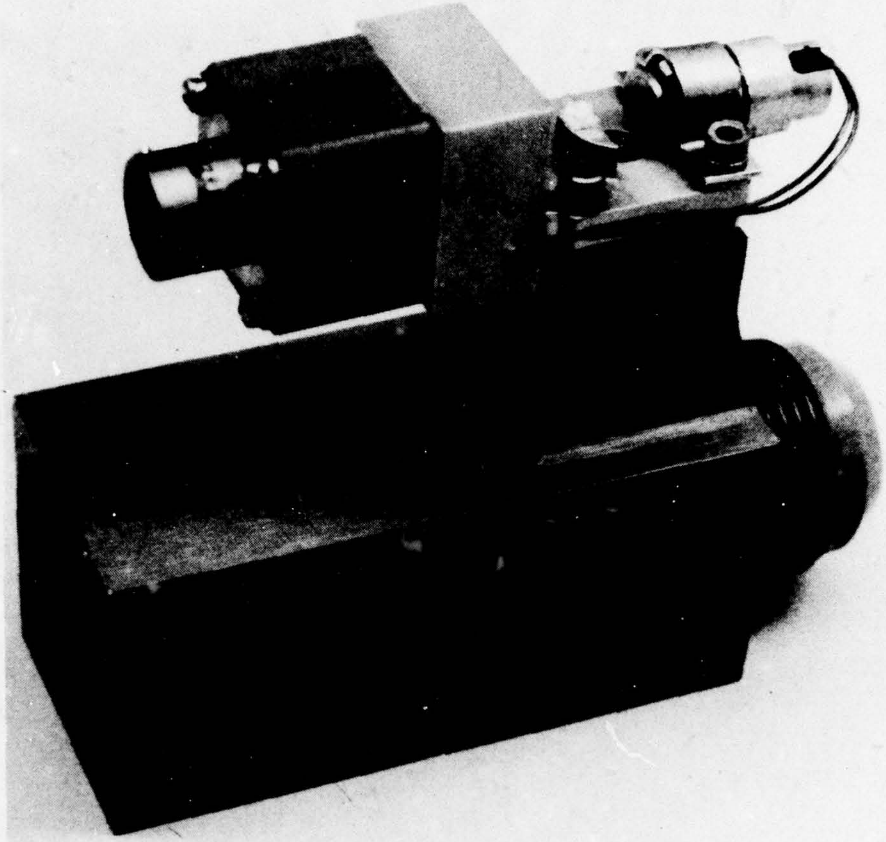
1087-058W

Figure 52. Pressure seal.



1087-059W

Figure 53. Typical high-performance hydraulic pump.



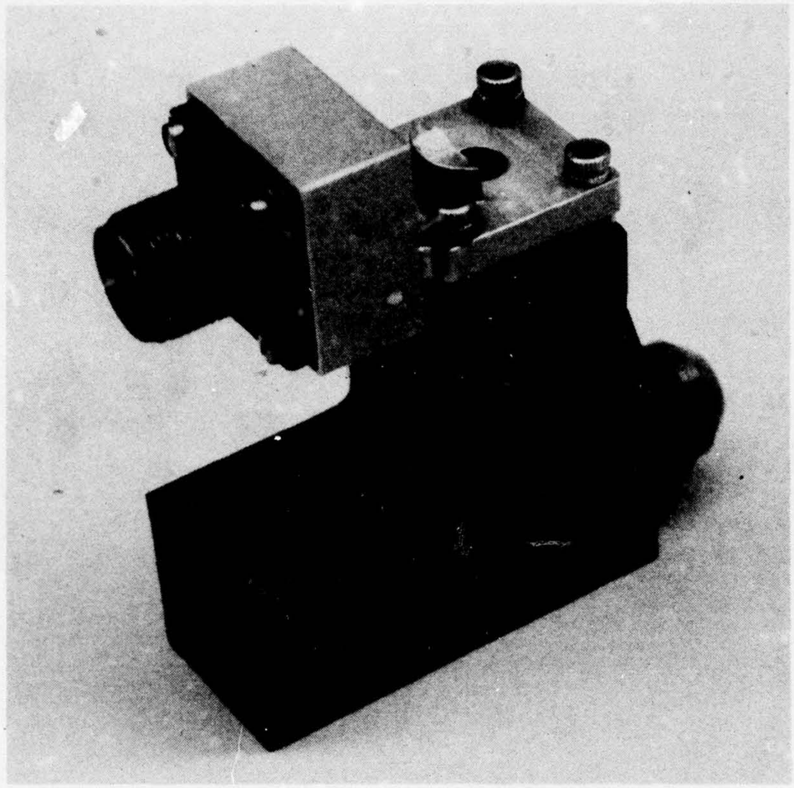
1087-060W

Figure 54. Quiescent flow sensor.

The flow sensor meters actual quiescent flow through a flow resistor that produces a desired differential pressure. The differential pressure, equated to a specific maximum permissible quiescent flow leakage, generates a signal. During normally higher system flow demand, the calibrated restrictor bypasses through additional flow passages at acceptable additional pressure differential across the entire sensor.

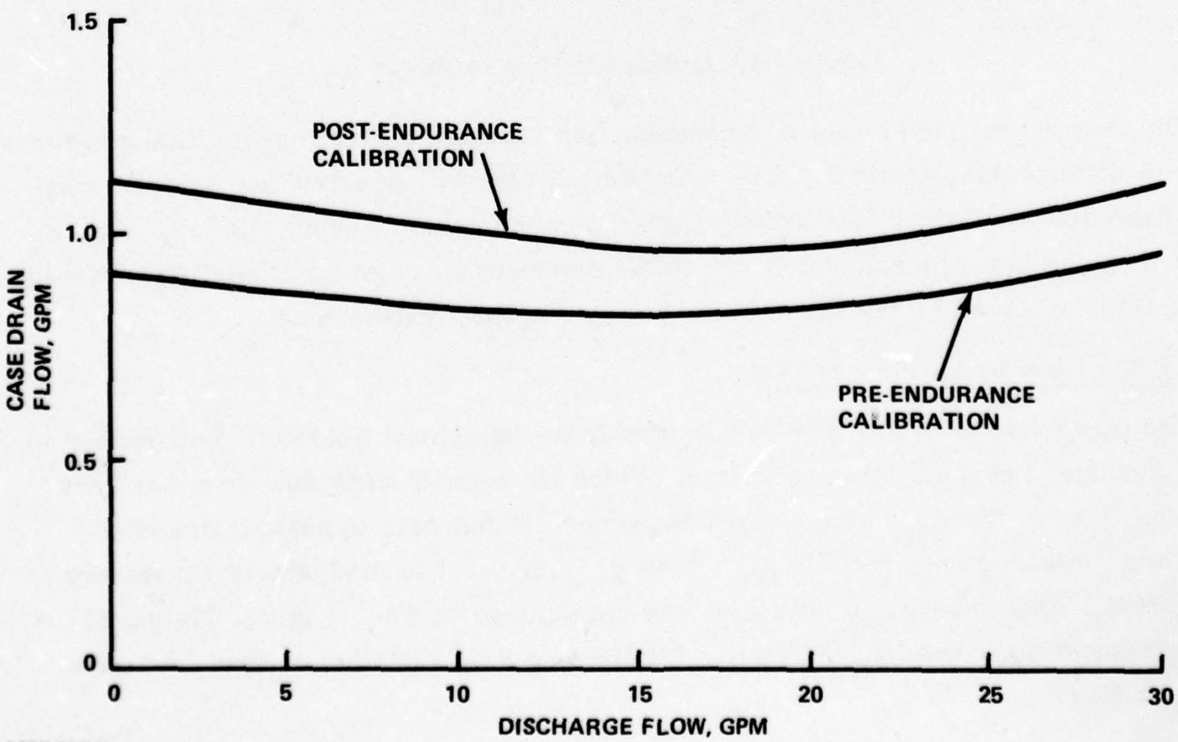
2.4.2 Pump Case Drain Flow Sensor

The pump flow case drain sensor is similar to the system quiescent flow sensor in design but does not incorporate a lockout device since pump case flow does not vary considerably over the hydraulic pump flow range. A fail-safe bypass device is incorporated, however, to preclude high back pressure due to inadvertent momentary block liftoff. Excessive pump case flow was established at 8 to 11 gpm. Figure 55 shows a typical pump case flow sensor. Figure 56 shows variation of case flow with discharge flow.



1087-061W

Figure 55. Pump case flow sensor.

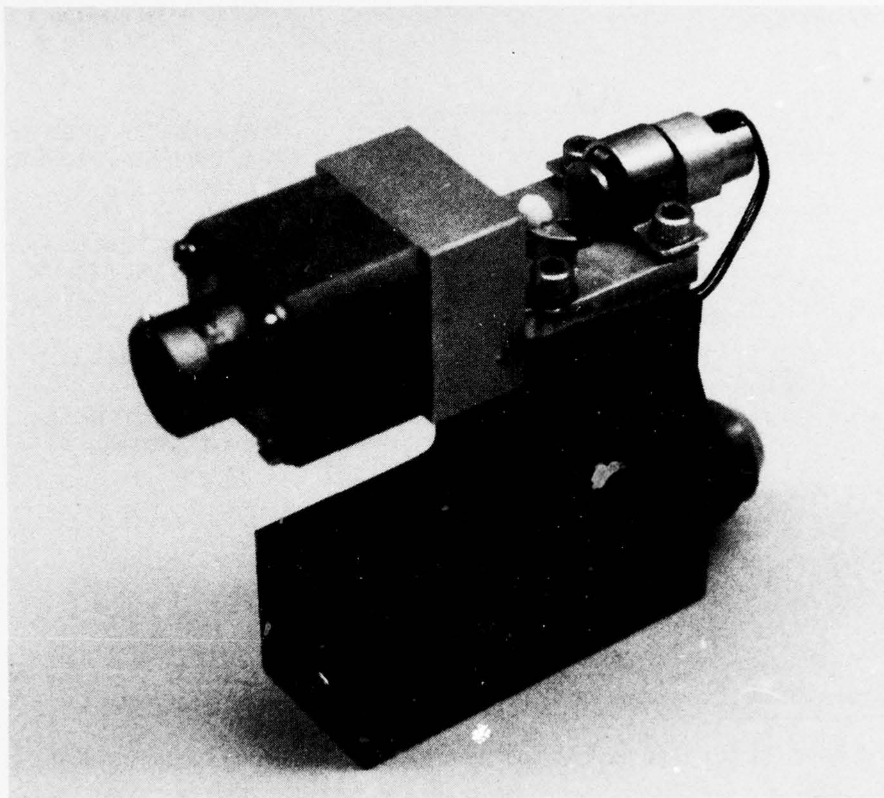


1087-062W

Figure 56. Variation of case flow with discharge flow.

2.4.3 Rudder Actuator Quiescent Flow Sensor

Excessive rudder actuator internal leakage is detected by an in-line flow sensor located in the pressure line. The unit is similar in construction to the system quiescent flow sensor, but is sized for a lower flow. Since normal rudder actuator quiescent leakage rates are very low, a value of 0.4 to 0.6 gpm was selected for the F-14 rudder actuator. Figure 57 shows the rudder actuator quiescent flow sensor.



1087-063W

Figure 57. Rudder actuator flow sensor.

2.4.4 System Pressure Switch

The system pressure switch serves two functions: it indicates low system pressure when the system is operating and provides panel circuitry to the flow sensors and elements.

The elapsed time meter on the panel is actuated by the pressure switch; the flow sensor circuits are dependent on the pressure circuit being on.

For this purpose, a switch (Figure 58) manufactured by Sigmanetics of Mountain Lakes, New Jersey, was incorporated.

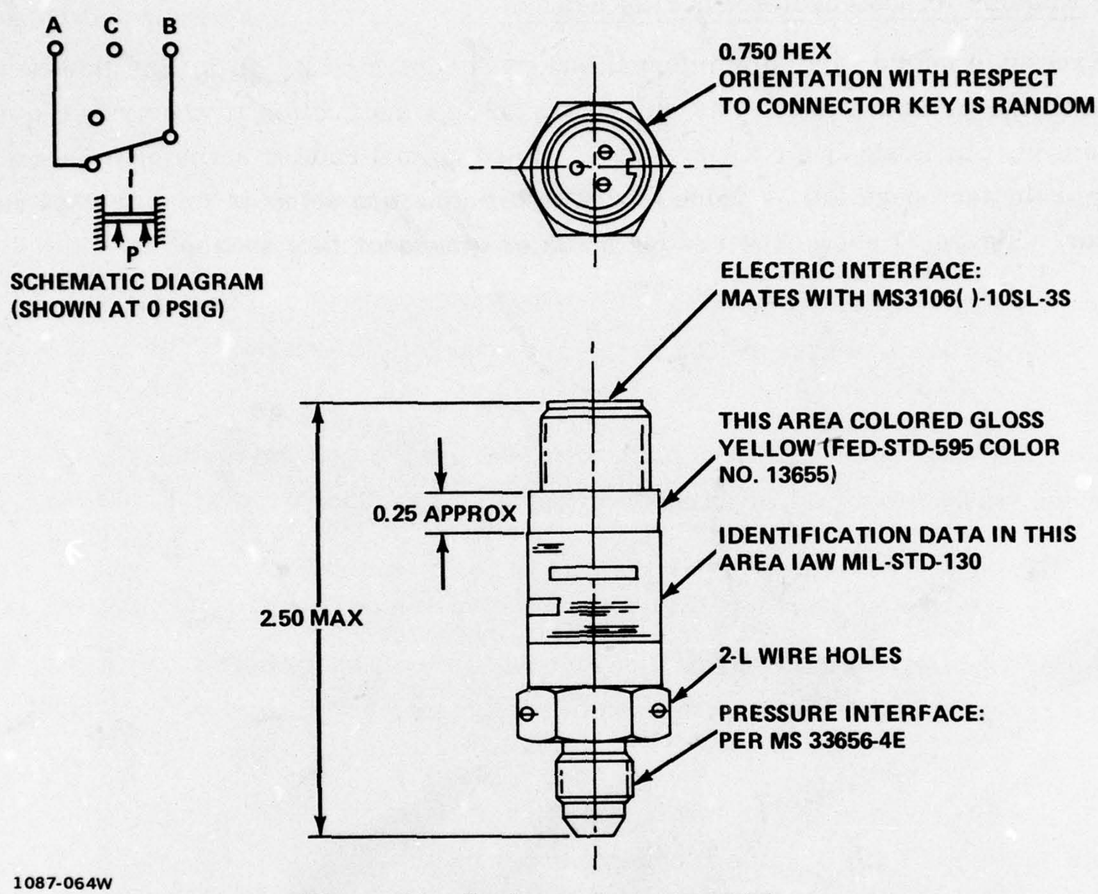


Figure 58. System pressure switch.

2.4.5 Case Drain Flow Temperature

Excessive case drain flow indicates system inefficiency or component degradation resulting in system fluid temperature rise. By installing a fluid temperature switch in series with the flow sensor, an excessive temperature limit can be detected.

Type II hydraulic systems operate at a 275 °F maximum. A value of 300 °F was selected as the trip limit on a Neo-Dyne model 1103TR119 manual reset temperature switch.

The switch probe is immersed in the fluid flow and contains n-propyl alcohol as the sensing medium. Temperature sensing is accomplished by exposing a welded corrosion-resistant steel diaphram to changes in pressure created by expansion of the fluid in the probe. Figure 59 shows pressure versus temperature of this fluid at constant volume. Temperature settings are determined by a force-balance interaction between the sensing diaphragm and a snap action Belleville spring system. An elec-

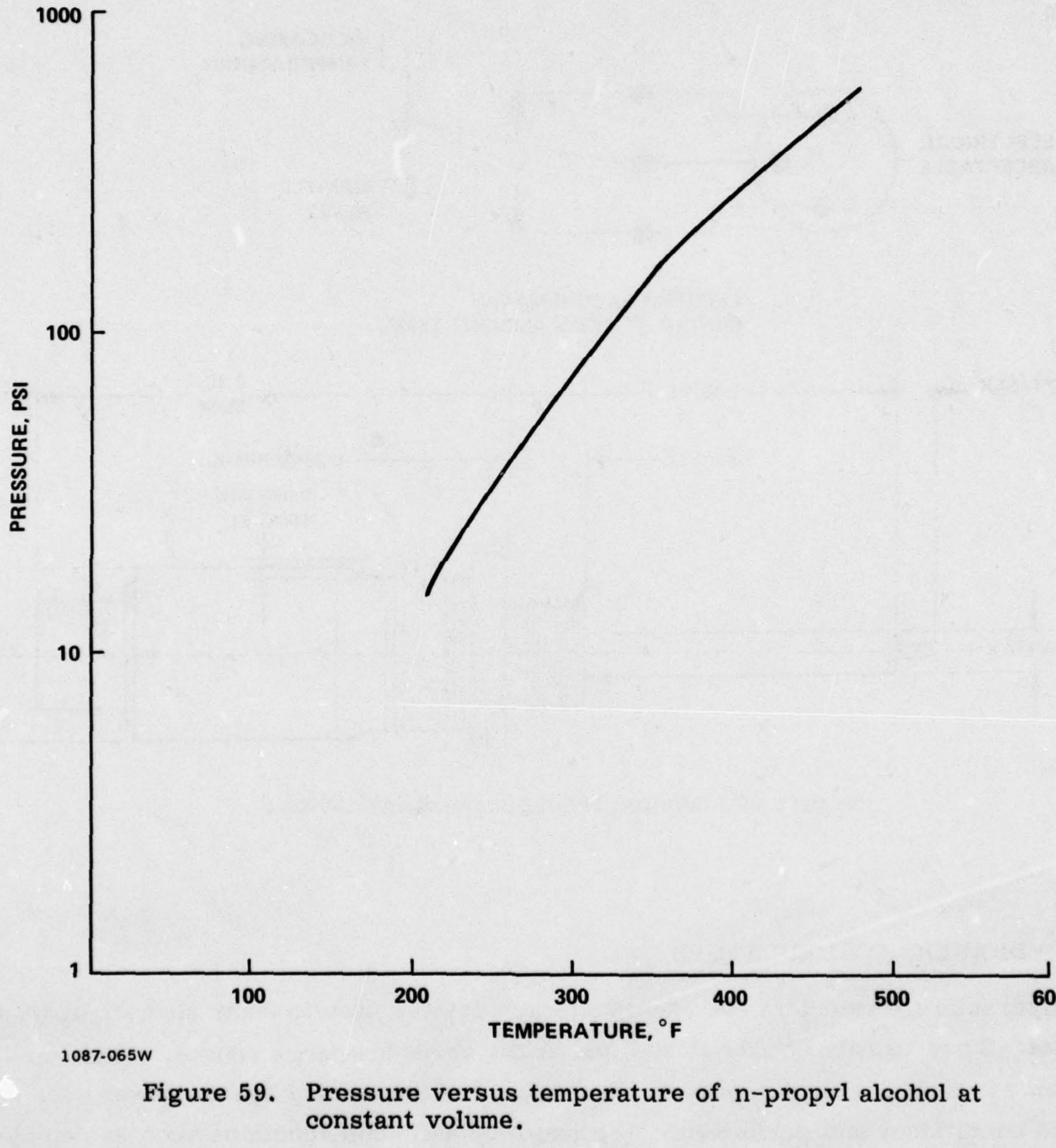


Figure 59. Pressure versus temperature of n-propyl alcohol at constant volume.

trical switch assembly positioned within the mechanism's stroke limit provides electrical circuit control at predetermined temperatures. The manual reset button functions as both a visual indication and a mechanism reset after switch actuation. The temperature switch is shown in Figure 60.

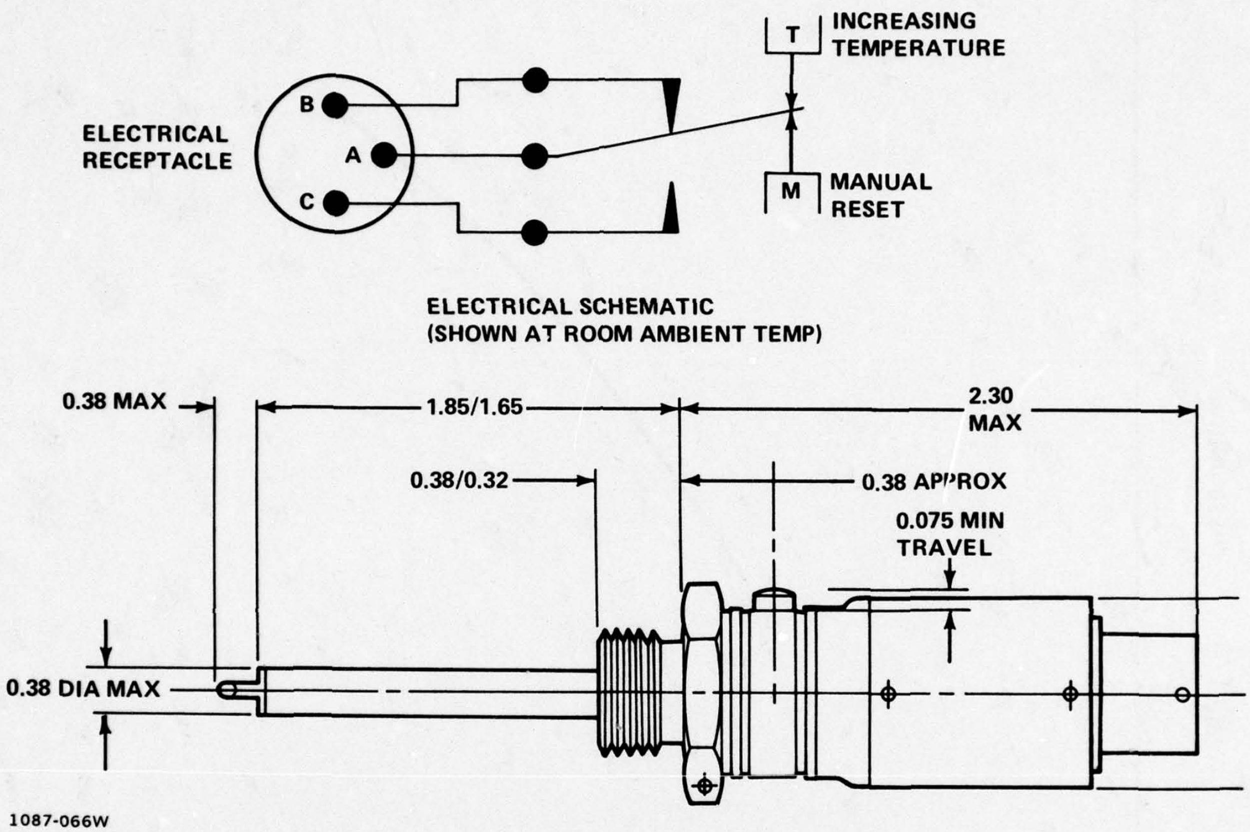


Figure 60. Manual reset temperature switch.

2.5 HYDRAULIC ACCUMULATORS

Hydraulic accumulators are energy storage devices used in many aircraft hydraulic systems. They usually employ stored gas as the variable energy source. Their applications include hydraulic pump ripple attenuation, momentary system power overdemand conditions, and performance of emergency actuation functions such as deploying a ram air turbine via a hydromechanical actuator.

The work output is dependent on initial precharge pressure, precharge temperature, and delta volume change caused by piston movement under constant temperature conditions:

$$P_1V_1 = P_2V_2$$

and

$$W = \int_{V_1}^{V_2} P\,dv$$

If we consider an isentrophic (no heat flow condition), then

$$W = K \int_{V_1}^{V_2} \frac{dv}{V}\,1.4$$

Since the variables are precharge pressure, precharge temperature, and piston displacement, the piston displacement for a final hydraulic system pressure of 3000 psi is a function of initial precharge conditions (Ref. 3, NADC TR 75168-30-Pg 33)

This monitoring effort was initiated to develop a method of determining accumulator precharge irrespective of whether the accumulator is fully or partially discharged. The variables required to determine this condition are charging pressure, temperature, and piston displacement.

Figure 61 shows the variation of piston displacement versus precharge pressure for a 50 in. accumulator. Figure 62 shows a plot of piston displacement versus precharge pressure versus temperature at constant 3000 psi pressure. Figure 63 is a nomograph developed to determine precharge pressure.

In order to measure accumulator piston displacement, precharge pressure (accumulator pressure), and precharge temperature, various methods were investigated to ascertain their suitability to accumulator applications. These specific sensing methods will be defined in subsequent paragraphs.

2.5.1 Piston Displacement Sensors

Several methods of determining piston displacement within a pressurized accumulator were investigated. They include:

- A direct type in which a rod attached to the piston passes through a dynamic seal
- Another direct type attached to the piston on the oil side to drive a rotary measuring device

- A reflected energy type which measures reflected IR energy from a movable surface.

The first direct type seemed to offer less development risk than the other two methods since the output could be processed easier with the microprocessor circuits. This direct type included a linear potentiometer with its axis parallel to the accumulator piston axis. By affixing the movable piston rod to the linear potentiometer, a direct relationship can be obtained by measuring resistance versus displacement. A 4 kΩ Bournes potentiometer was chosen for this application. Figure 64 shows this configuration installed in an accumulator.

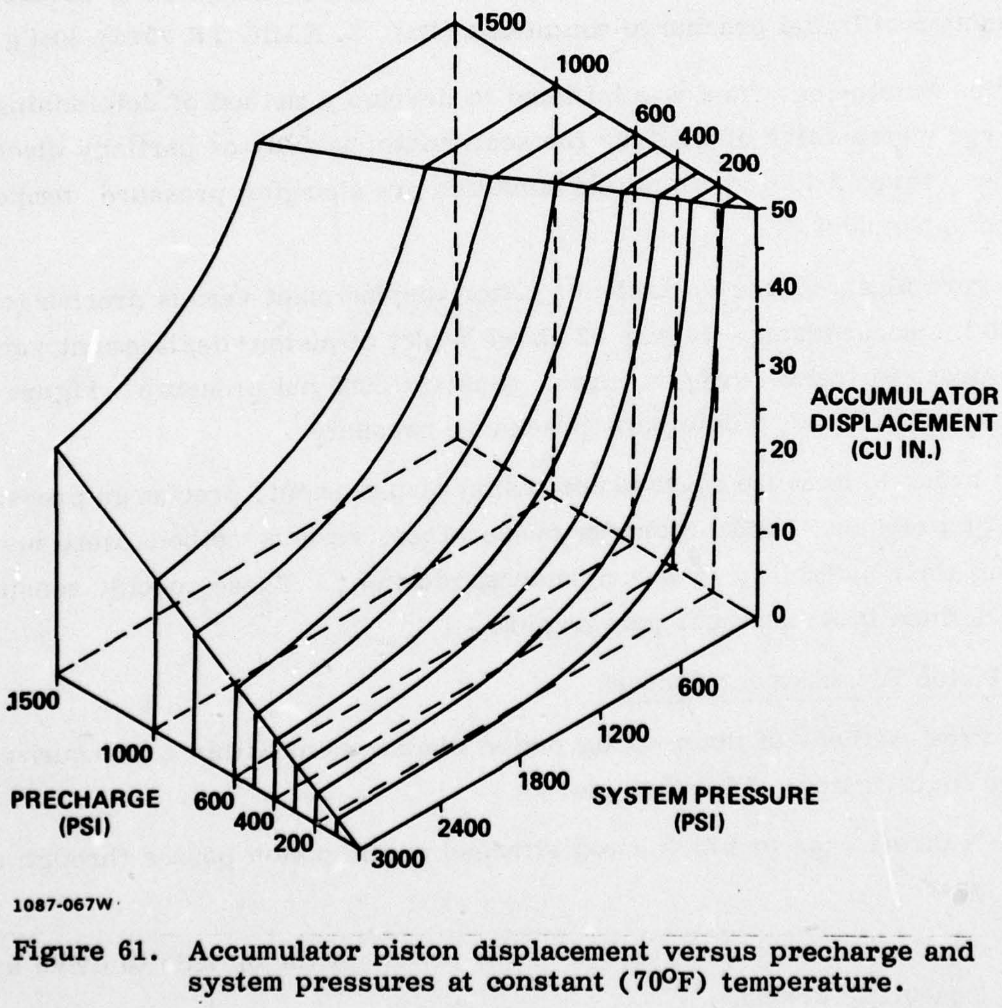


Figure 61. Accumulator piston displacement versus precharge and system pressures at constant (70°F) temperature.

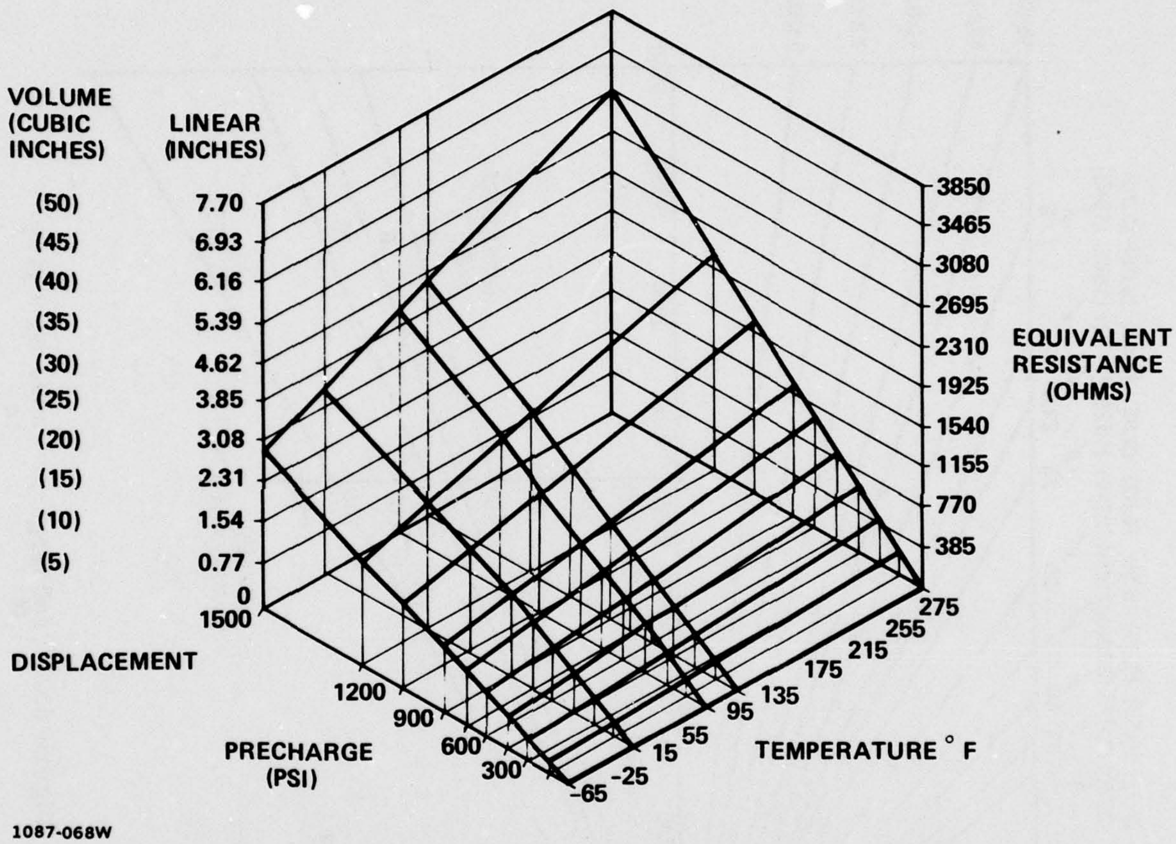


Figure 62. Accumulator piston displacement versus precharge pressure versus temperature at constant (3000 psi) system pressure.

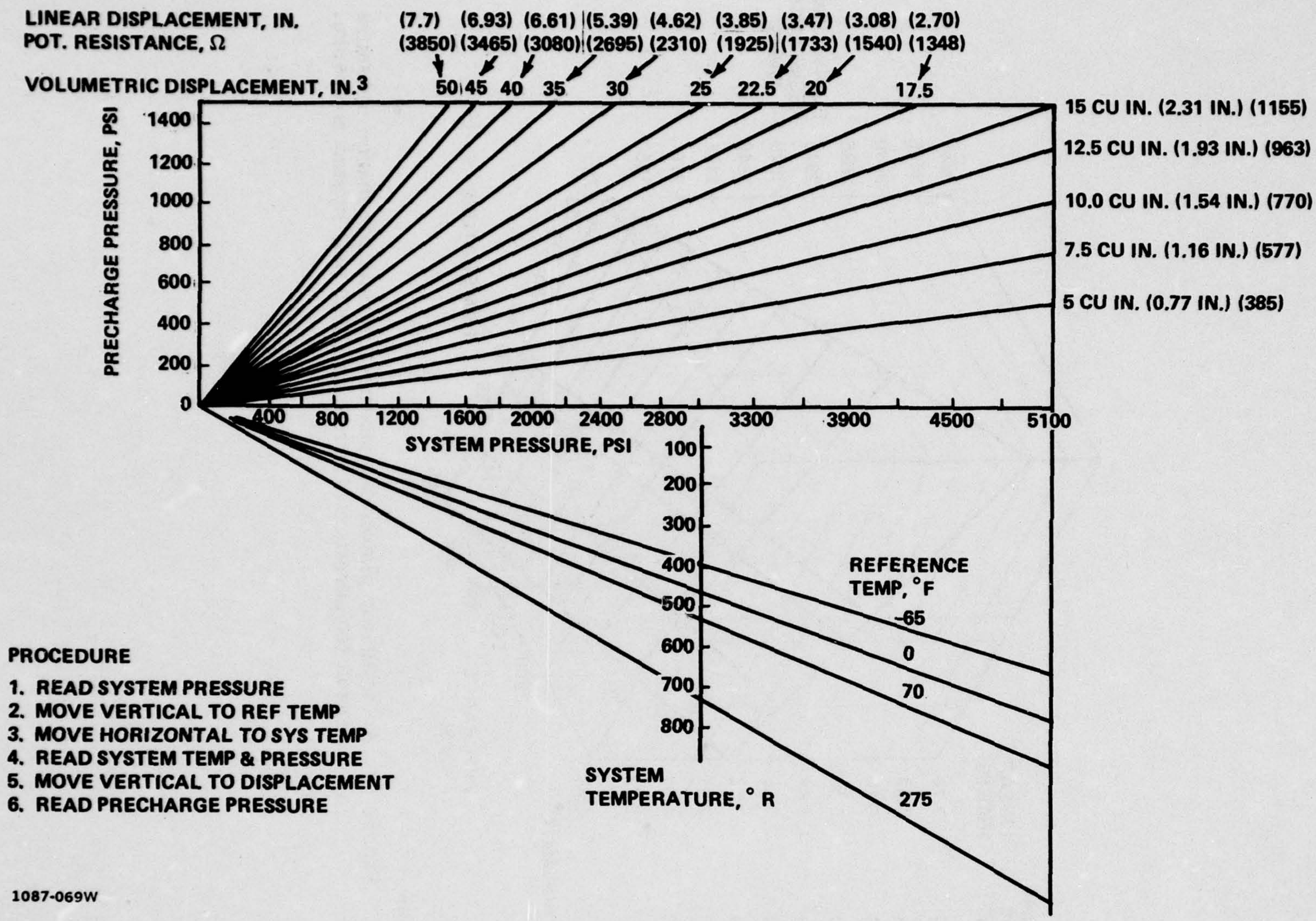


Figure 63. Precharge pressure nomograph.

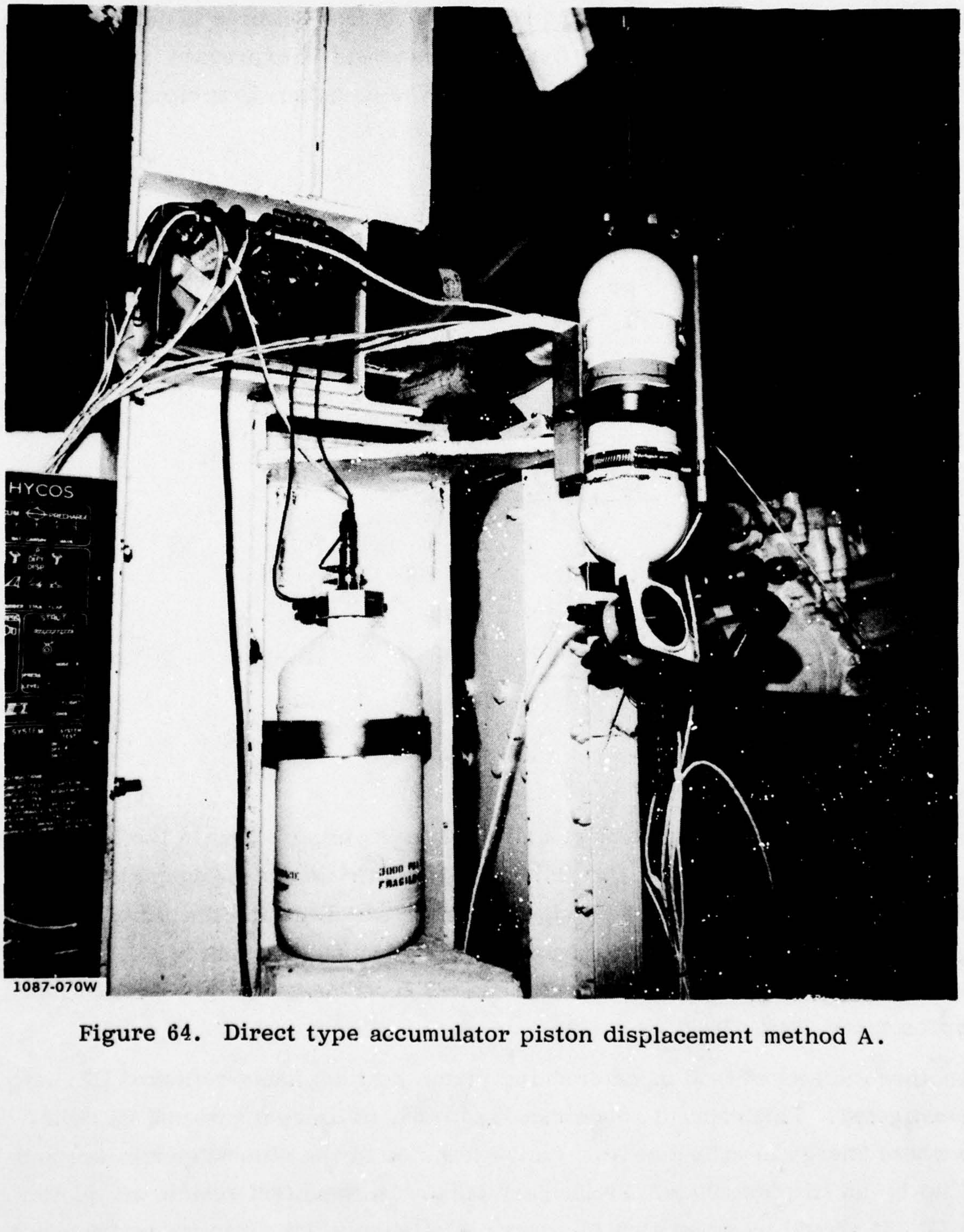


Figure 64. Direct type accumulator piston displacement method A.

Typically, it has been necessary to empty the fluid from the accumulator to measure precharge pressure. However, utilizing a newly developed equation involving system pressure, volume, temperature, and displacement it is now possible to determine precharge pressure without dumping the fluid. Displacement is expressed as a ratio of resistances measured by a linear potentiometer. The equation, graphically displayed in the nomograph of Figure 63, is derived as follows:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$P_1 = P_{Precharge}\ (P_{pr}),\quad V_1 = 50\ in^3.,\quad T_1 = 70\ °F = 530\ °R$$

$$P_2 = P_{system}\ (P_{sys}),\quad V_2 = \text{Volumetric Displacement} = 50\left(\frac{R}{3850}\right)$$

$$T_2 = (T_2 + 460)°R$$

$$\frac{(P_{pr})\ (50)}{530} = \frac{(P_{sys})\ (50)\ (R/3850)}{(T_2 + 460)°R}$$

$$(530)\ (P_{sys})\ (50)\ (R/3850) = (P_{pr})\ (50)\ (T_2 + 460)$$

$$P_{pr} = \frac{(530)\ (P_{sys})\ (R/3850)}{(T_2 + 460)}$$

Direct type B (Figure 65) employed a pressure vessel attached to the liquid side of the accumulator. Movement of the piston wound and unwound a constant spring force motor which drove a 10-turn 20 kΩ potentiometer. Only the connector leads pass through the pressure vessel. Since the effect of hydraulic pressure on the potentiometer was not known and the pressure vessel added considerable weight to the system, this approach was less attractive.

Another indirect method of determining piston position using reflected IR energy was investigated. This concept, shown in Figure 66, utilizes an external IR light source whose energy is reflected from the bottom side of the accumulator piston and picked up by an IR photodiode. Preliminary nonpressurized test results are plotted in Figure 67. It should be noted that the curve is relatively flat up to approximately 4 in. of stroke and then changes markedly. The test circuit wiring is shown in Figure 68.

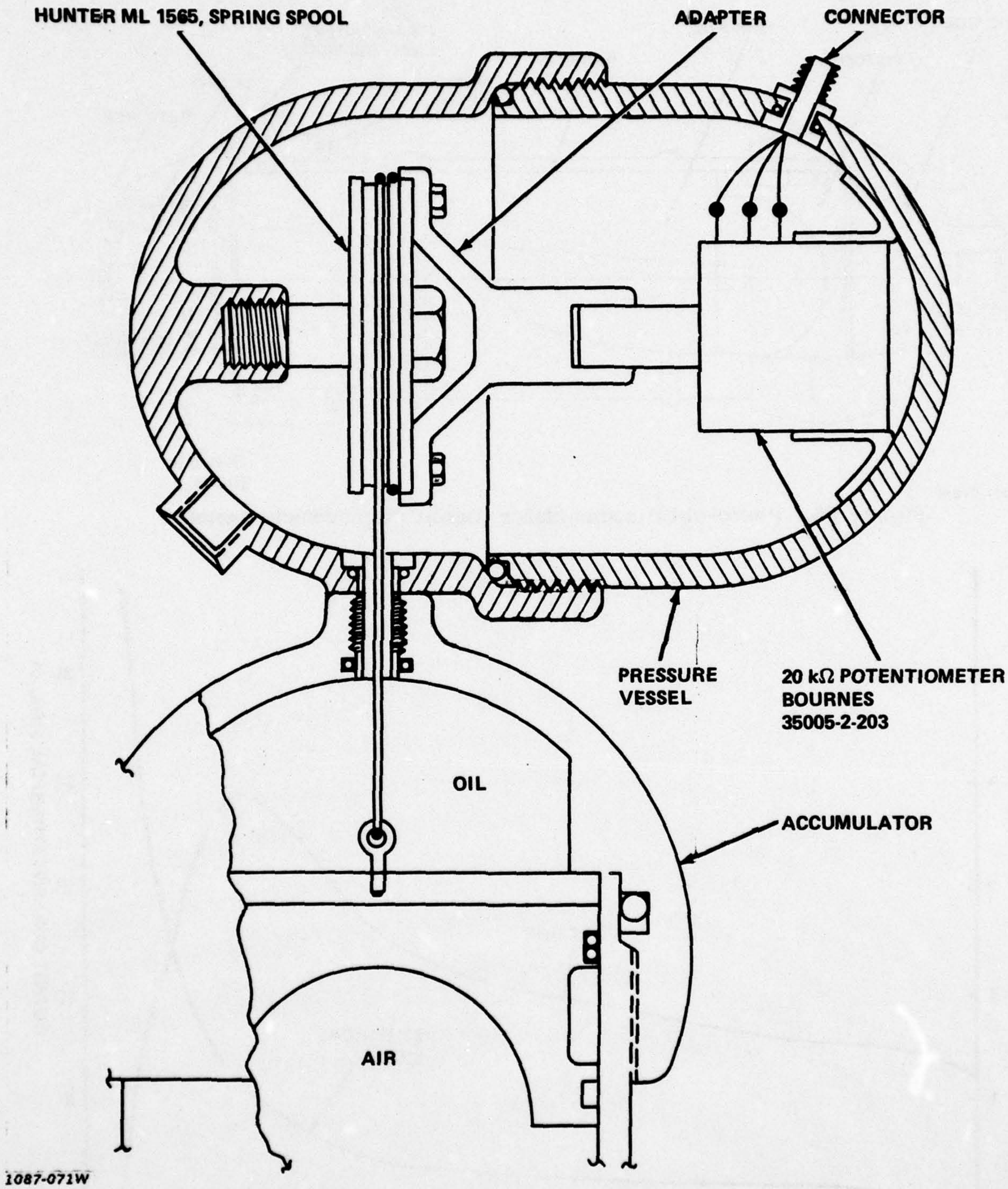


Figure 65. Direct type accumulator piston displacement method B.

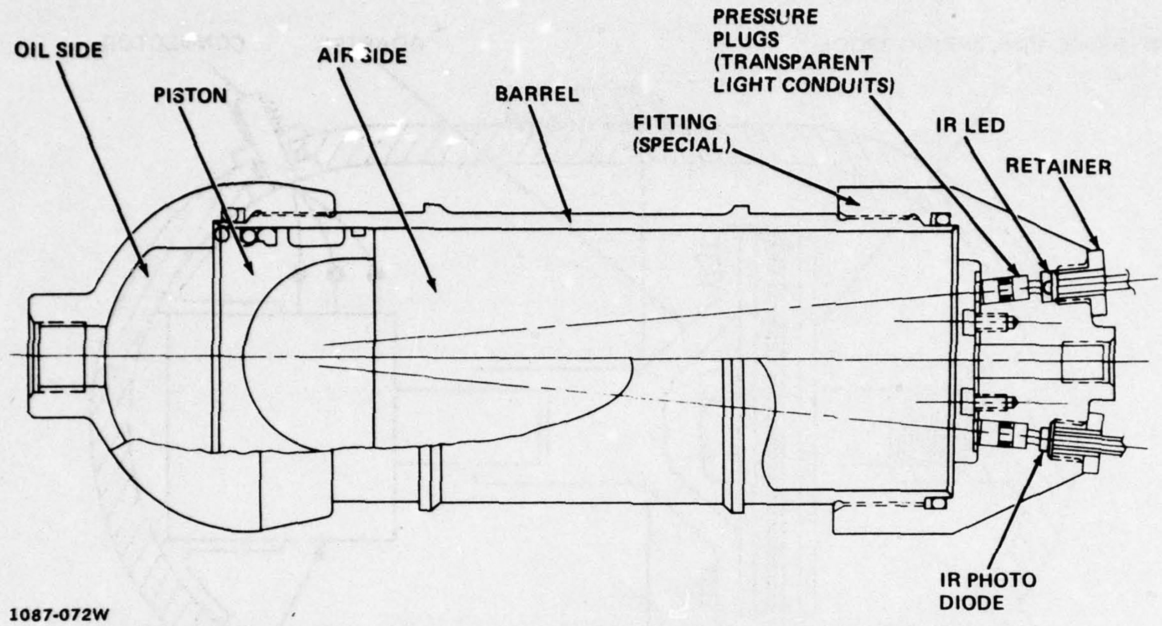


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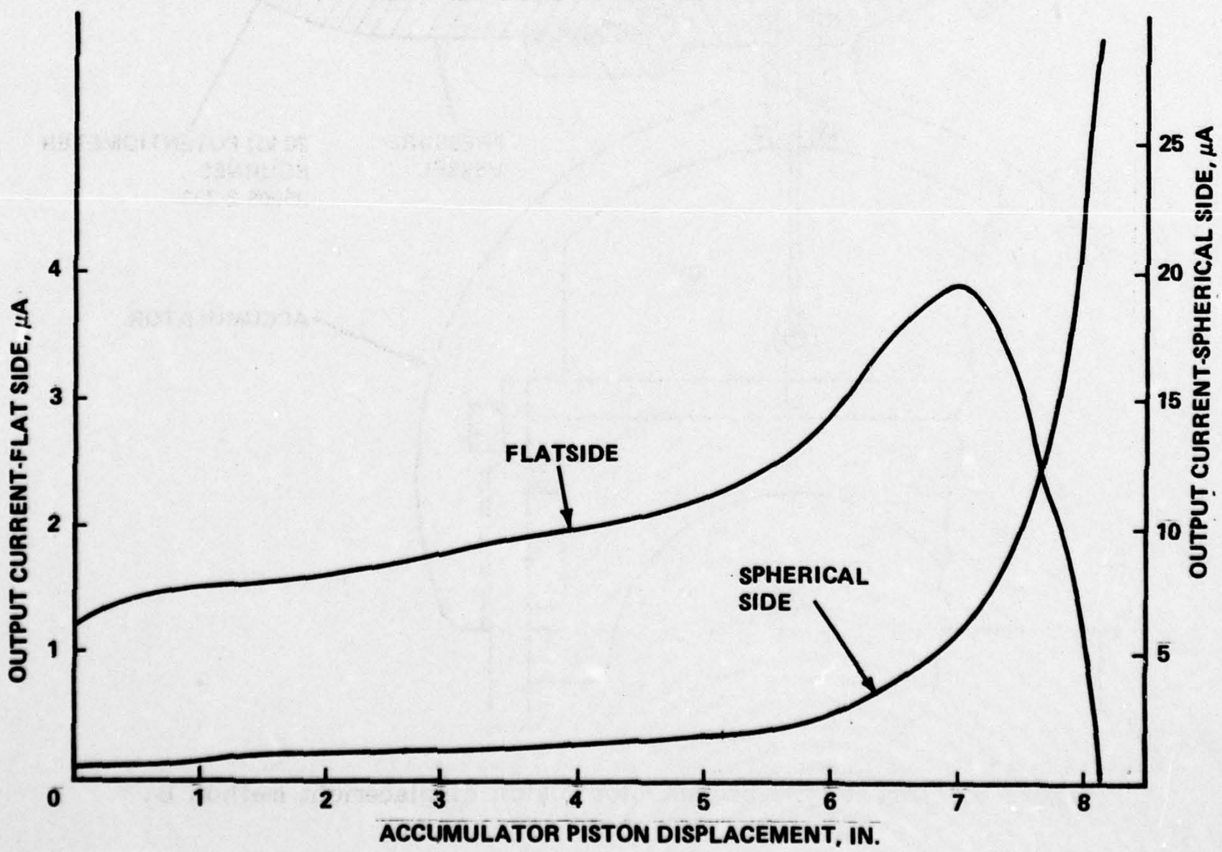
Figure 66. Photo-optic accumulator piston displacement sensor.



1087-073W

Figure 67. Photo-optic accumulator piston sensor test results.

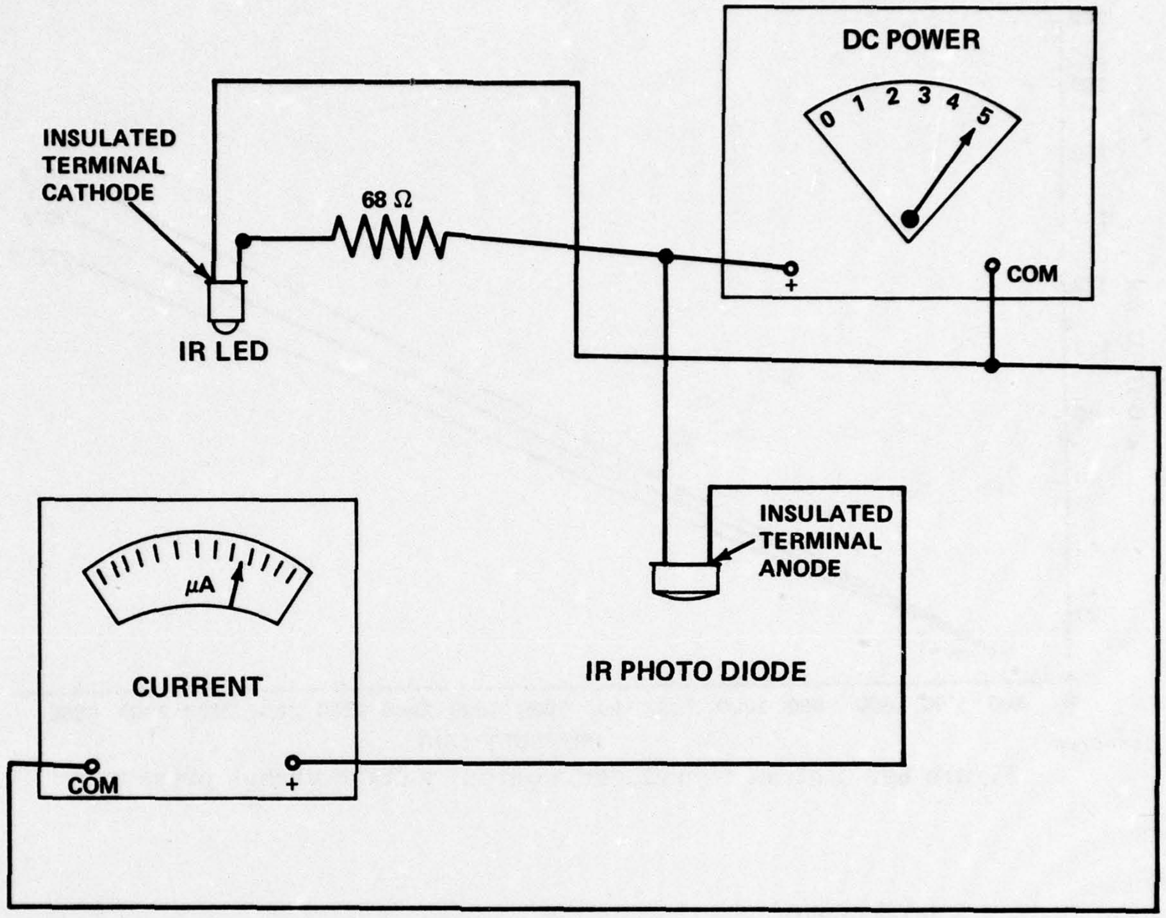


Figure 68. Photo-optic displacement sensor wiring diagram.

2.5.2 Pressure Transducers

In order to sense accumulator pressure, manufacturers of miniature pressure transducers were investigated. One unit was supplied by Entran Devices of Little Falls, New Jersey, and the other by Kulite Semiconductor of Ridgefield, New Jersey.

The Entran EPS-1032 miniature pressure transducer is a thread-mounted semiconductor strain-gage sensor which fits into a 10-32 UNF threaded boss. The transducer employs a face seal and has a full-scale output of 143 mV at 3000 psi pressure with 5 V input (room temperature). There is, however, a temperature shift when tested at -40 and 250 °F. Calibration curves for this unit, shown in Figure 69, are very linear over the normal operating range (0-3000 psi). Sensitivity of the transducer is 0.0485 mV/psi. The unit is normally compensated for linearity by using an external compensation module from 80 to 180 °F. The wiring diagram is shown in Figure 70.

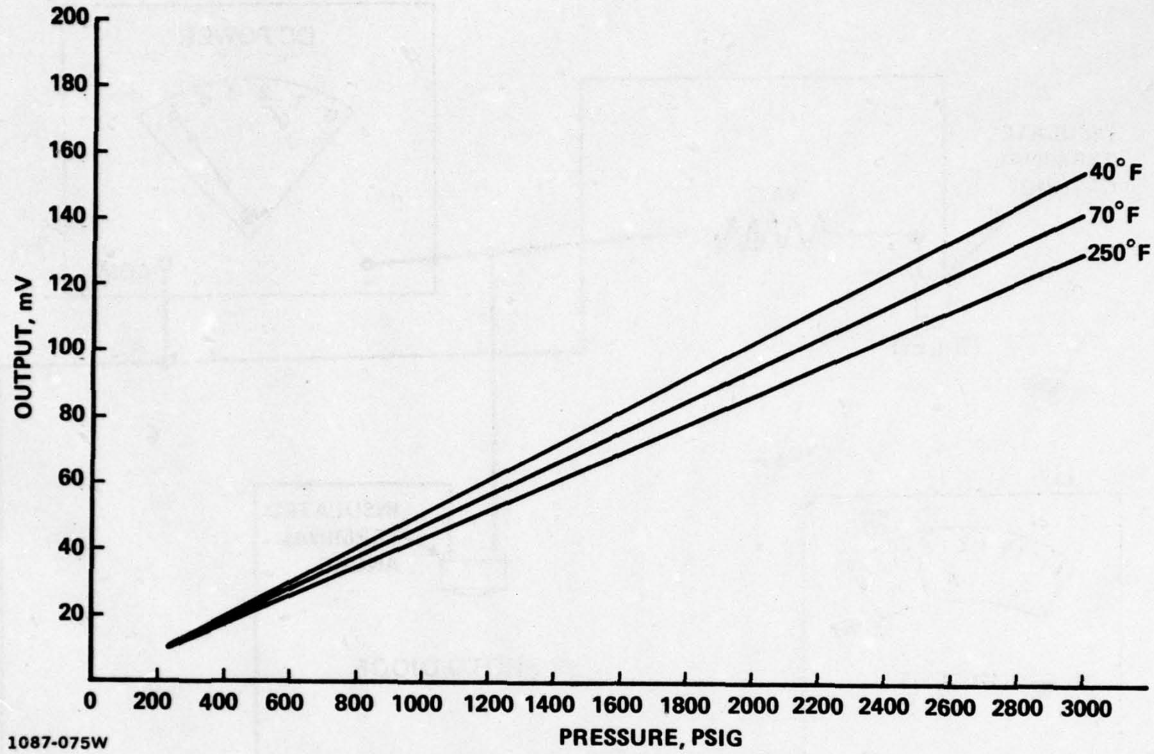


Figure 69. Entran transducer: output voltage versus pressure.

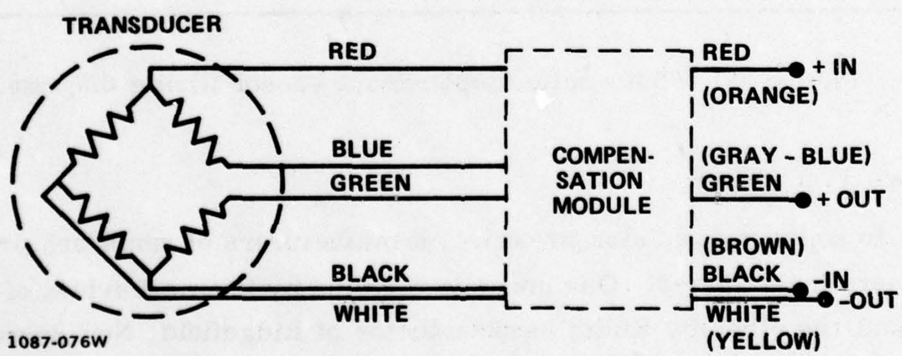


Figure 70. ESP-1032 pressure transducer wiring diagram.

Performance data for the Kulite Semiconductor pressure transducer is listed in Table 6. Since the intended application encompassed broader temperature ranges, an extended calibrated temperature range was made. Table 7 shows performance data for the Entran ESP-1032 transducer. Envelope dimensions for a typical unit are shown in Figure 71.

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HYDRAULIC DIAGNOSTIC MONITORING SYSTEM.(U)

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TABLE 6. KULITE SEMICONDUCTOR TRANSDUCER DATA

- MODEL XTMS-1-190-2000, S/N 4303-3-145 (N2-80)
- RATED PRESSURE: 2000 PSI
- MAXIMUM PRESSURE: 3000 PSI
- EXCITATION: 10 VDC (20 VDC MAXIMUM)
- SENSITIVITY: 0.0375 mV/PSI
- ZERO PRESSURE OUTPUT: ± 3% FS
- THERMAL EFFECT ON ZERO: ± 2% FS/100 °F
- THERMAL EFFECT ON SENSITIVITY: ± 2% /100 °F
- COMPENSATED TEMPERATURE RANGE: 80 TO 180 °F
- OUTPUT IMPEDANCE: 613 Ω
- INPUT IMPENDANCE: 2616 Ω

1087-077W

TABLE 7. ENTRAN ESP-1032 TRANSDUCER DATA

- MODEL: EPS -1032-2500 (.33), S/N 10 H8H-C1-1
- TYPE: MINIATURE PRESSURE
- RANGE: 2500 PSIG
- EXCITATION: 6.0 TO 8.0 V
- OVERPRESSURE: 4000 PSIG
- OPERATING TEMPERATURE: -60 TO 250 °F
- TEMPERATURE COMPENSATION: -60 TO 250 °F
- EXCITATION: 6 VDC
- SENSITIVITY: 0.0469 mV/PSIG AT 77 °F
- THERMAL SENSITIVITY SHIFT, mV/100 °F: < ± 2%/100 °F
- THERMAL ZERO SHIFT, mV/100 °F: < ± 1.5% FS/100 °F
- INSTALLATION TORQUE: 15 IN.-LB
- IMPENDANCE: INPUT: 430 Ω

  OUTPUT: 239 Ω

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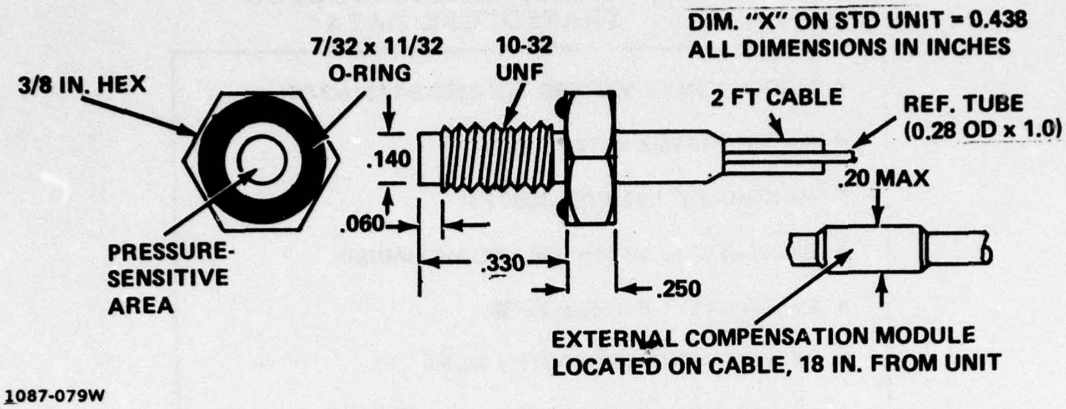

Figure 71. Pressure transducer envelope.

A third pressure transducer, manufactured by National Semiconductor, was also tested at room temperature. The model LX 1460A calibration curve, provided in Figure 72, shows that the voltage output is linear with 15 VDC excitation but reaches saturation at 1500 psi when the excitation voltage is reduced to 5 VDC. HYCOS operates at 5 VDC.

2.5.3 Temperature Sensor

The temperature sensor used in the accumulator circuit is the same as that used in the hydraulic reservoir circuit. This sensor assembly uses an analog device: the AD540C integrated circuit temperature transducer. A complete description and test data can be found in Subsection 2.1, Hydraulic Reservoirs.

2.6 RUDDER DIFFERENTIAL DISPLACEMENT CIRCUIT

In some aircraft systems, mechanical disconnects have occurred due to disengagement of a bolt or clevis pin in the mechanical/electromechanical linkage. This would not be evident in aircraft which do not have flight-control surface display indicators on the panel.

System disconnects can be detected by comparing an input signal to a corresponding output signal. If the output signal does not follow or null out the input signal, microprocessor circuitry will indicate a disconnect condition until corrective action is taken.

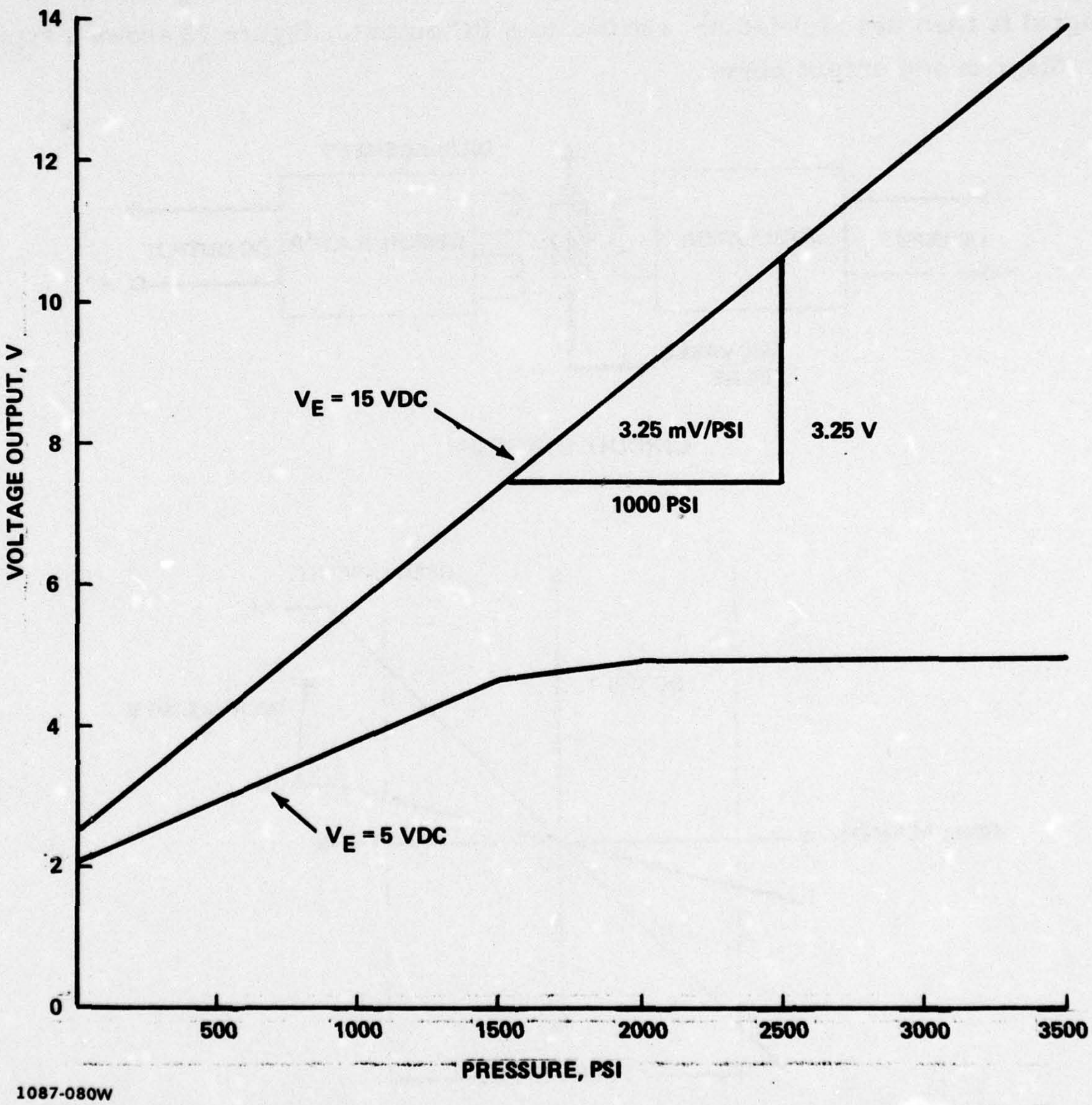

Figure 72. National Semiconductor pressure transducer calibration curve.

Two basic types of systems were considered:

- DC-DC displacement transducers
- Linear or rotary potentiometers.

In DC-DC displacement transducers, an oscillator is used to generate an AC signal which then couples a multiple-leg transformer to a moveable core. The coupling efficiency of the core then determines the position of the element being measured. The signal is then demodulated or rectified to a DC output. Figure 73 shows a typical circuit diagram and output curve.

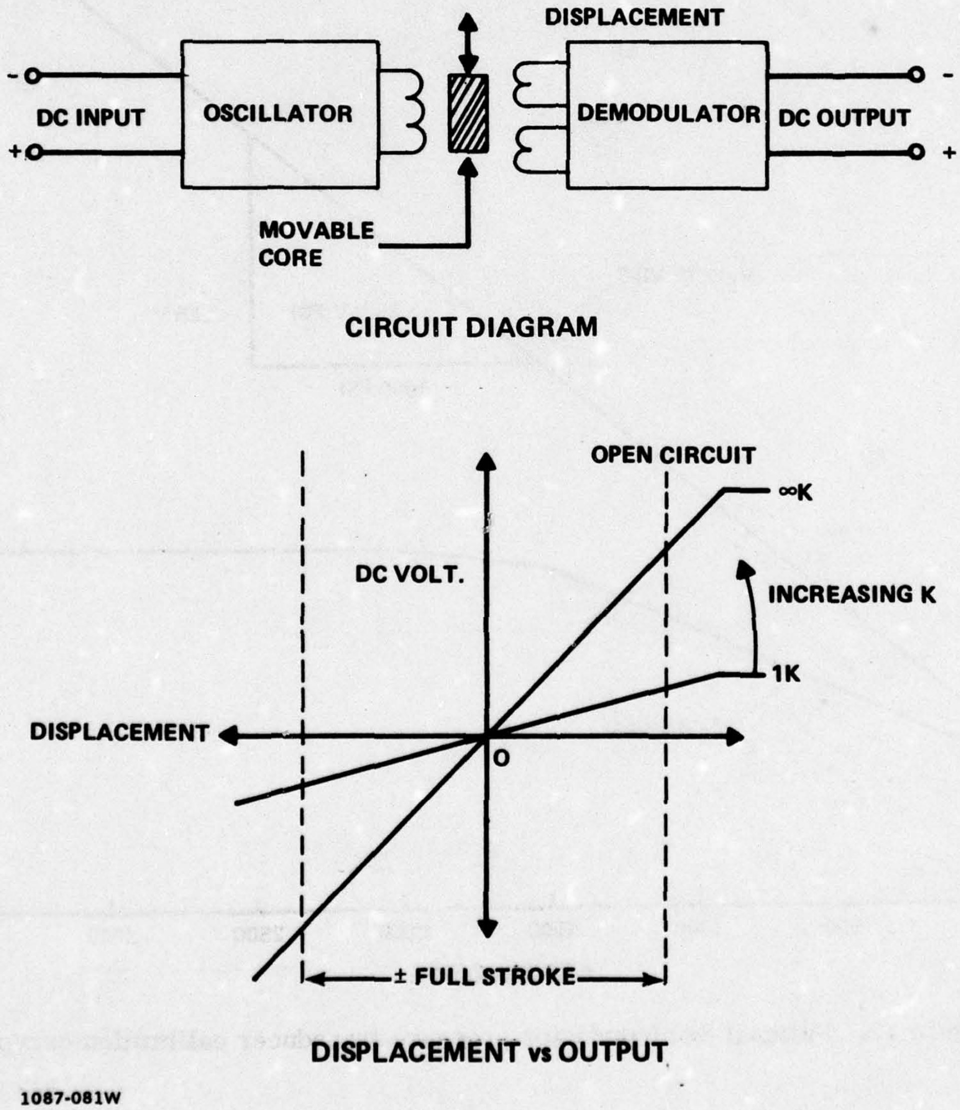

Figure 73. DC-DC displacement transducer.

Linear or rotary potentiometers are another type of displacement measuring device. Rotary or rectilinear movement of the input shaft positions a contactor (wiper) along or around a continuous resolution resistance element. These devices have practically zero backlash, are insensitive to vibration, and are compact and lightweight. In addition, their cost is low. Rotary transducers are made in multiples of 360° rotation; some cover 3600° (10 turns). Figure 74 shows typical transducer wiring diagrams and a representative plot.

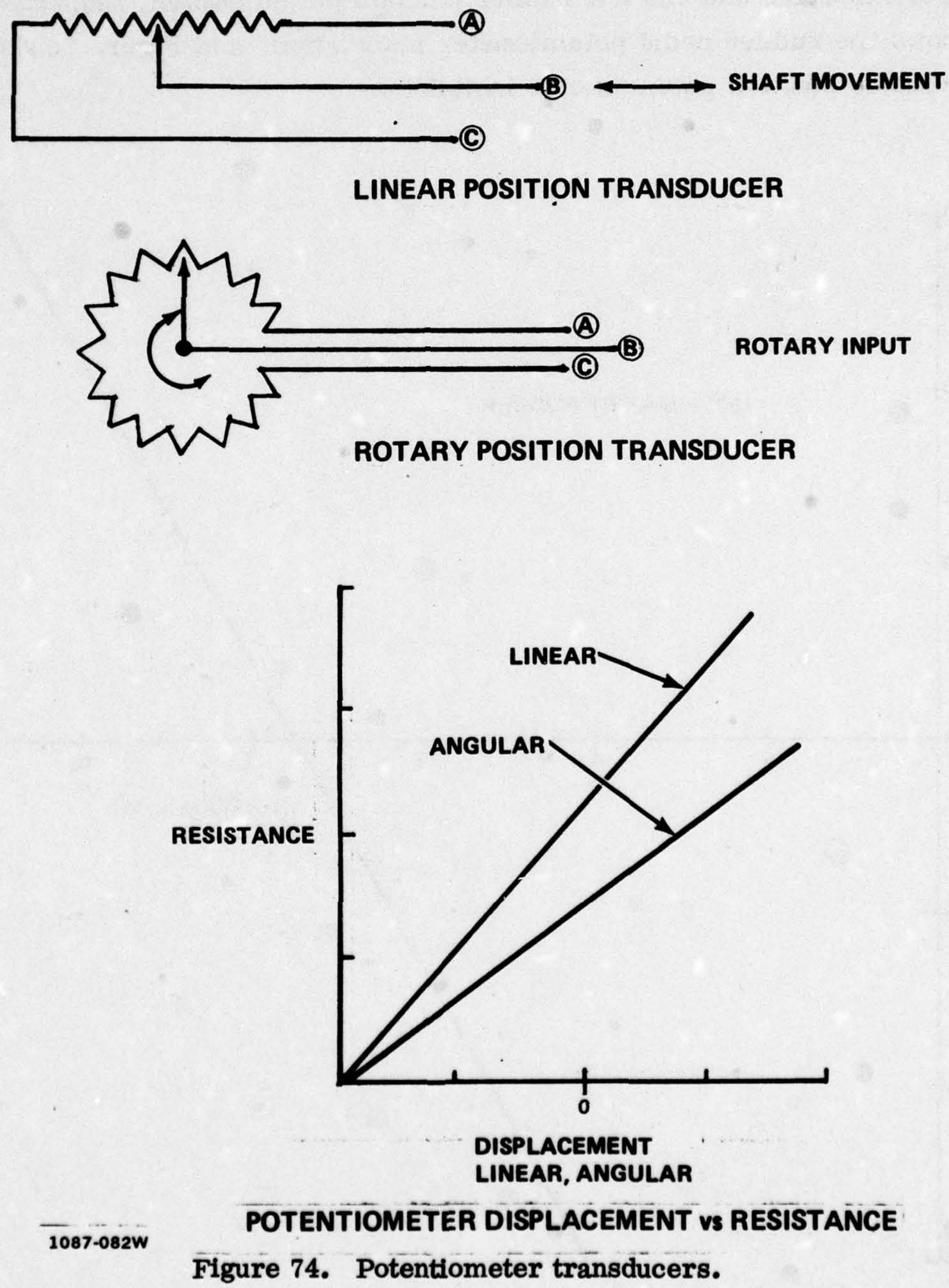

Figure 74. Potentiometer transducers.

The signal on both transducers are fed to a bridge circuit which detects a variation or omission of an input signal. When this imbalance occurs, the HYCOS circuit is energized.

Table 8 lists pertinent information on transducers used on the F-14 Rudder Actuator Circuit. Figures 75 and 76 show the calibration curves for the rudder pedal position potentiometer and the left rudder position potentiometer, respectively. Figure 77 shows the rudder pedal potentiometer installation, and Figure 78 shows the rudder actuator position potentiometer installation.

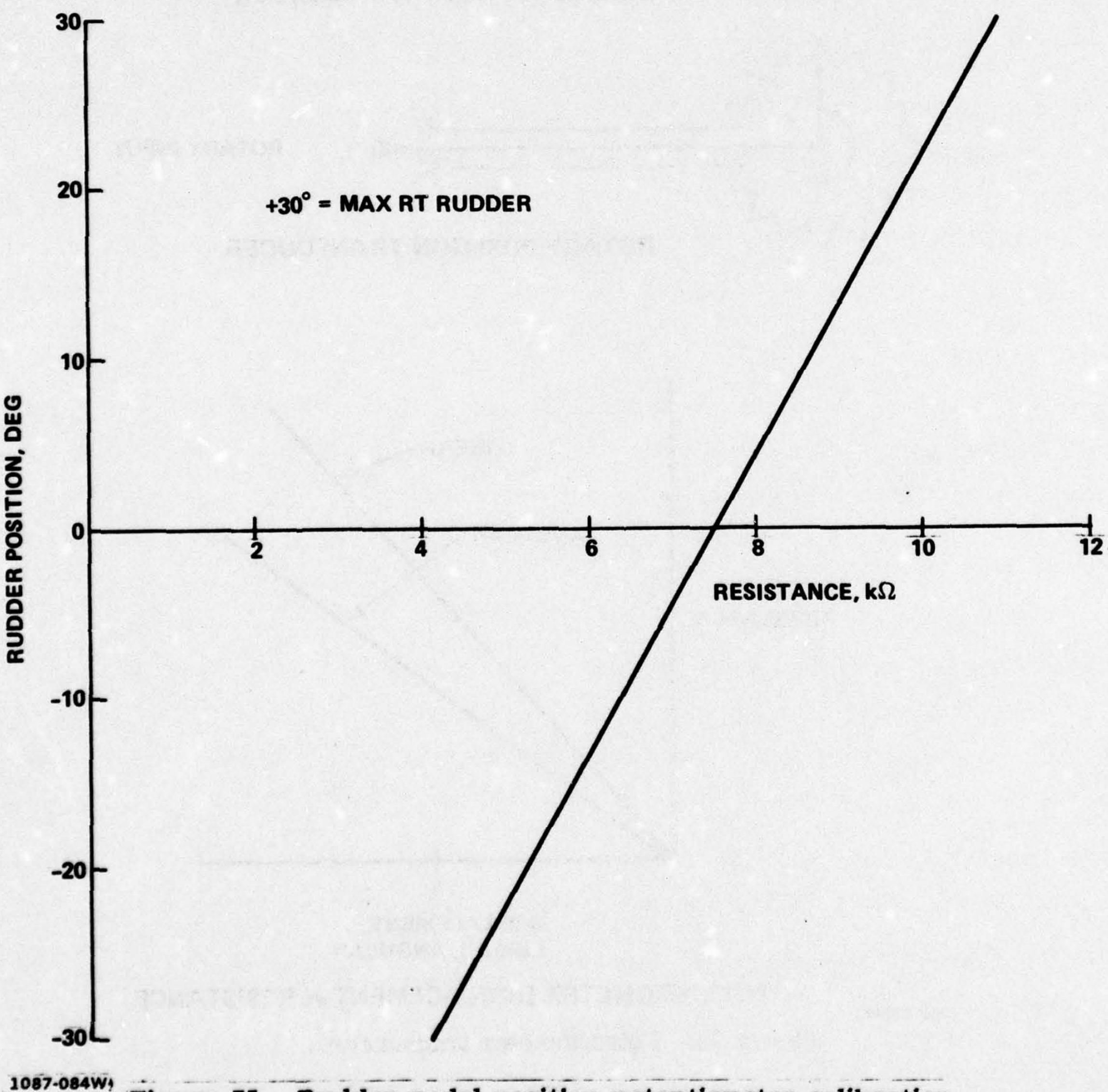

Figure 75. Rudder pedal position potentiometer calibration.

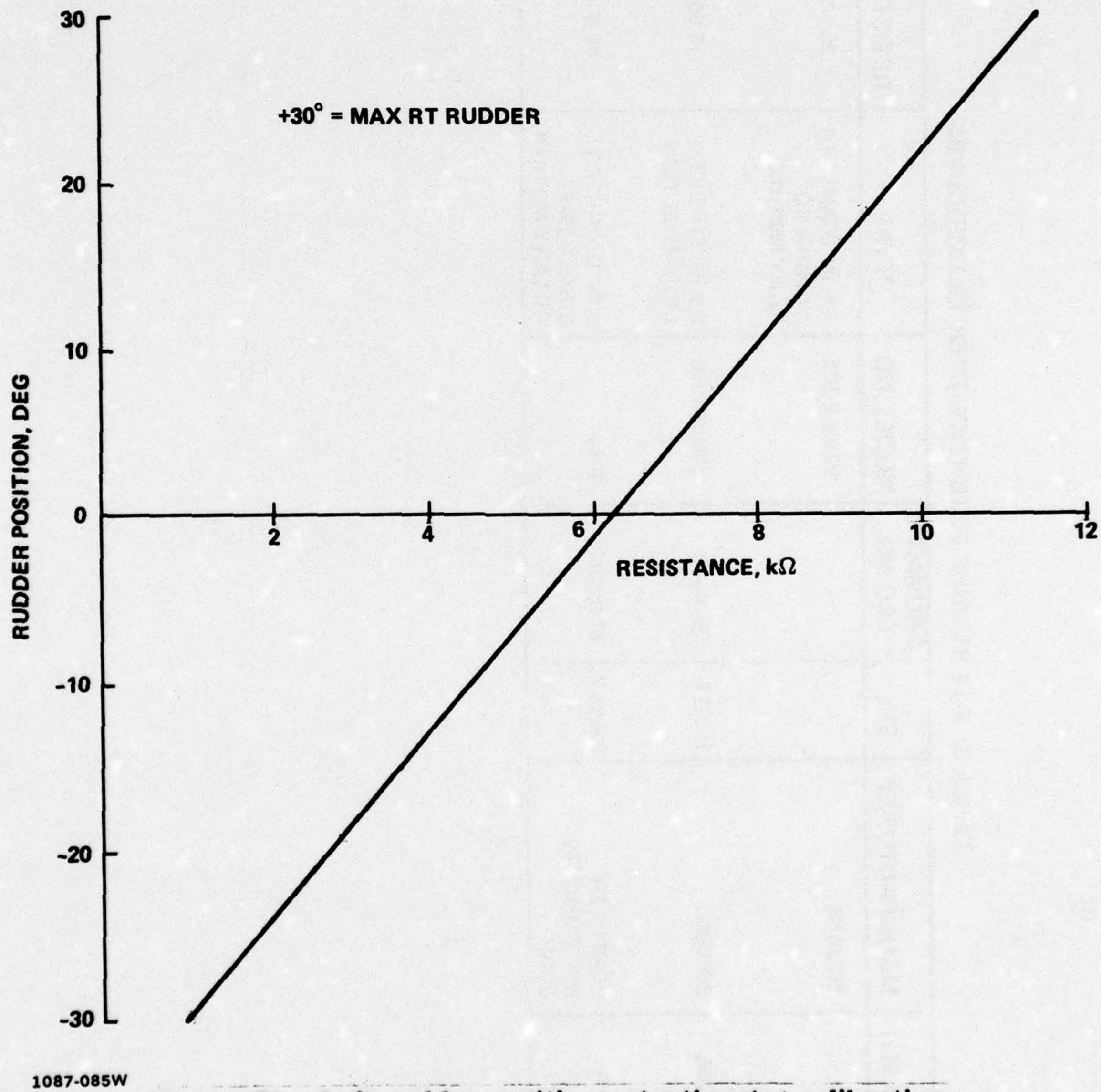

Figure 76. Left rudder position potentiometer calibration.

TABLE 8. F-14 RUDDER POTENTIOMETER TRANSDUCERS

MEASUREMENT	MANUFACTURER	S/N	GRUMMAN TAG NO.	MODEL NO.	TYPE	RESISTANCE, Ω	LINEARITY
RESERVOIR LEVEL POSITION INDICATOR	BOURNS	–	–	3500S-2-203	7/8 IN. DIAMETER 10-TURN RO-TARY MOTION	20,000 ± 3%	± 0.2%
RUDDER PEDAL POSITION INDICATOR	BOURNS	153177	607440N	2001763015	6.0 IN. STROKE – LINEAR MOTION	12,000	NOT AVAIL-ABLE
LEFT RUDDER POSITION INDICATOR	COMPUTER INSTRUMENTS CORP.	22684-7	611657N	505	5 IN. DIAMETER SINGLE-TURN ROTARY MOTION	10,000	0.25%

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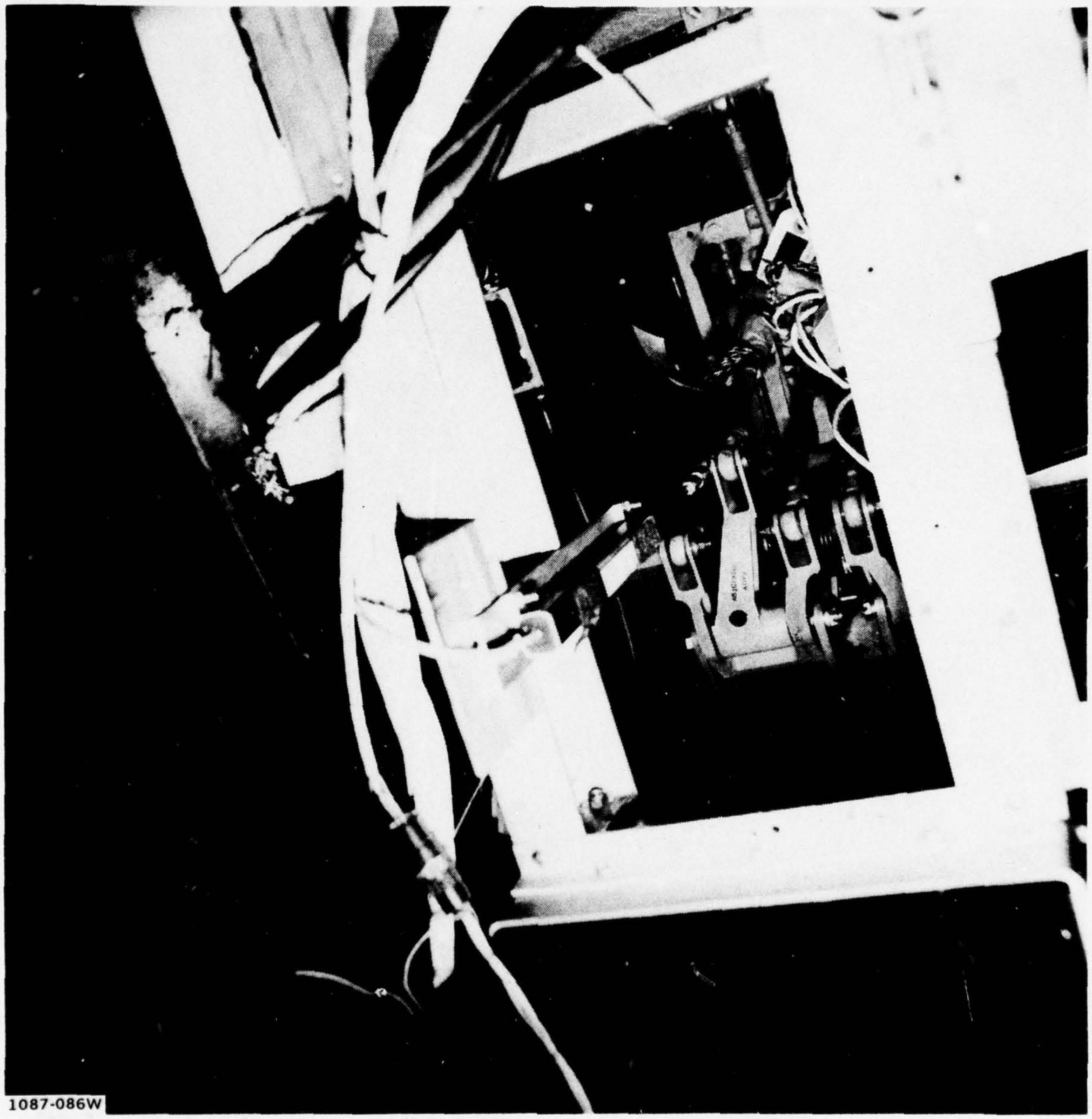

Figure 77. Rudder pedal potentiometer installation.


1087-089W

Figure 78. Rudder actuator position potentiometer installation.

2.7 OPTICAL DESICCANT SENSOR

Some hydraulic system reservoirs are pneumatically pressurized utilizing regulated pressurized air supplied by compressor bleed air.

A desiccant is used to dry the make-up air used to pressurize the reservoir. The cartridges are replaced at periodic intervals predicated on vehicle system usage. In order to remotely detect a saturated condition, a colored desiccant cartridge is placed in series with the existing one.

The selected cartridge (Figure 79) was made by Delaval Special Products Division and conforms to Grumman Specification No. 205. It measures approximately 5 in. by 3 in. long, has a transparent housing, and is rated for 100 psi operating pressure. The unit contains approximately 2.6 $in.^3$ of silica gel in conformance to Military Specification MIL-D-3716, type IV. The initial color of the dessicant is deep blue to pale blue, depending on the desiccant condition. As the unit becomes saturated, the color changes from pale blue to pink.

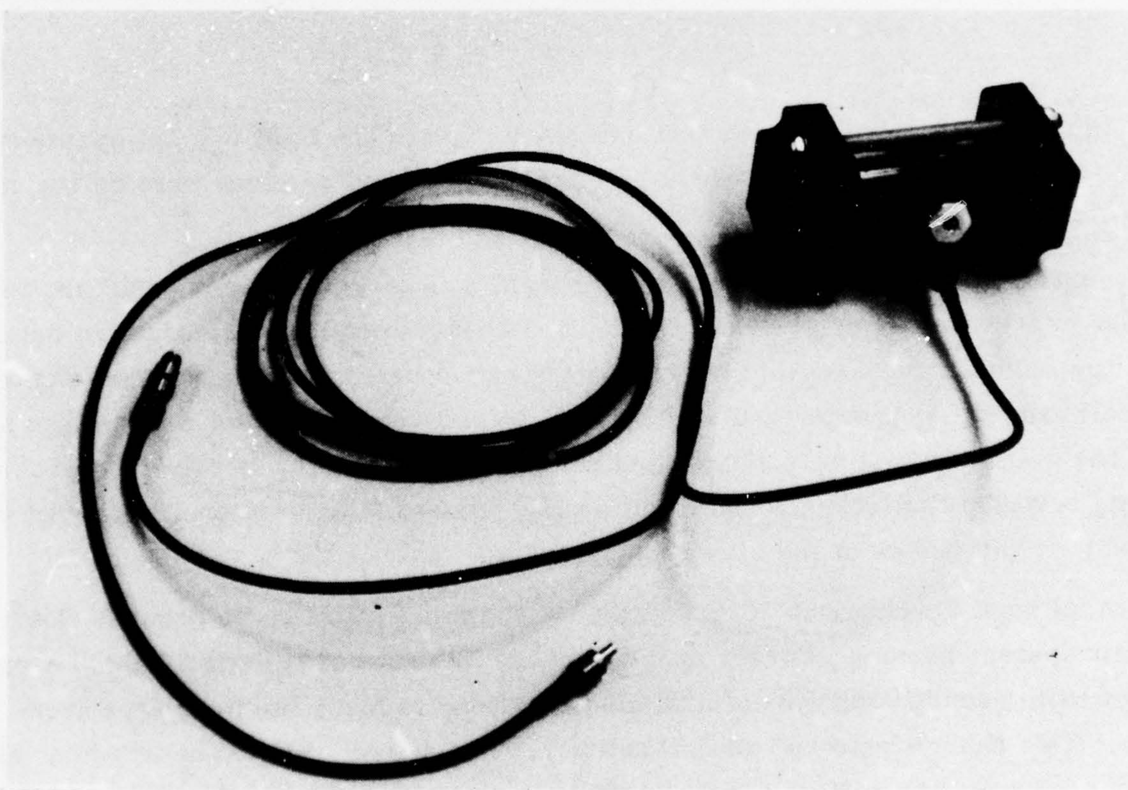

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Figure 79. Remote indicating desiccant color sensor.

Reading this condition remotely is accomplished by using a reflected colored light from the irregular granules of desiccant through the transparent housing. Figure 80 illustrates the concept employed.

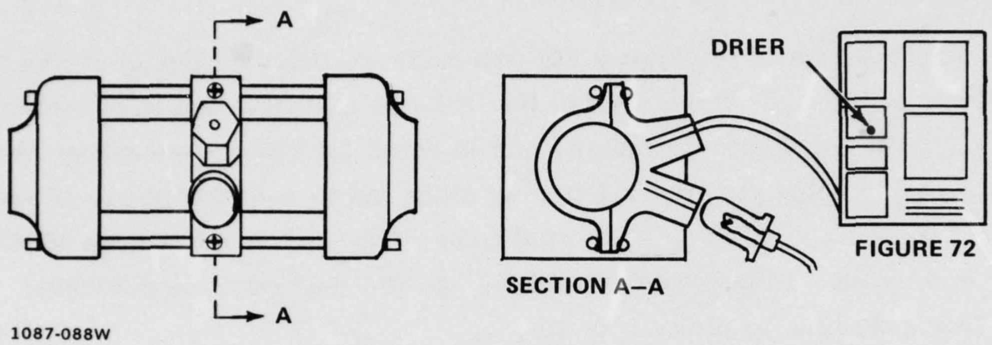

Figure 80. Moisture detector fiber-optic circuit.

Initial test results revealed that a major portion of the light was being reflected by the transparent housing since the light transmitter and receiver were on the same axis.

Further development dictated that the light source approach the desiccant perpendicular to the housing axis. Various reflected angles were tested in order to determine the maximum reflected light. This condition occurred with an included angle of 30° between the transmitter and receiver. A second sensor housing was made to support the grain of wheat light source and the fiber-optic terminal receiver. Subsequent testing revealed that color transmission became evident but the intensity was not discernable to the viewer at the display panel.

Additional development effort dictated that the light source be brought closer to the transparent housing in order to increase the intensity of reflected light. A light source with a condensing lens was obtained in order to focus the light rays at one point. This change improved the reflective properties but, due to the irregular shape of the desiccant, the reflected light scatters in many directions and makes the reflection of colored light difficult. As a final attempt, a condensing lens was used on the reflected light source to intensify the color.

Section 3

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11. Machine Design, March 16, 1978, Page 130.

APPENDIX A

TEST REPORT

A.1 Development Test Report for HYCOS Utilizing the F-14A Flight Controls Simulator and Component Testing

A.2 Acceptance Test Procedure for Temperature Compensated Pressure Switch, Manufacturer's P/N 1500PT89

CONTRACT REQUIREMENTS	CONTRACT ITEM	MODEL	CONTRACT NO.
		HYCOS	N62269-78-C-0041

REPORT

NO. A51-314-P-72.51 DATE: March 16, 1979

DEVELOPMENT TEST REPORT FOR HYCOS SYSTEM UTILIZING THE F-14A FLIGHT CONTROLS SIMULATOR AND COMPONENT TESTING

CODE 26512

PREPARED BY: R. L. Kennedy
R. L. Kennedy

CHECKED BY: W. Yearsley
W. Yearsley

DEPARTMENT:

SECTION: Struct./Mech./Envir./Test Section

TECHNICAL APPROVAL: John J. Duzich
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APPROVED BY: E. Anderson
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APPROVED BY:

APPROVED BY: D O Bagwell
D. O. Bagwell
Naval Air Development Center

REVISIONS

DATE	REV. BY	REVISIONS & ADDED PAGES	REMARKS

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TABLE OF CONTENTS

1.0 <u>INTRODUCTION:</u> This document is intended to outline developmental testing of the "HYCOS" checkout system as installed in the F-14A Flight Control System Simulator and to demonstrate its suitability for use in an aircraft. Component testing and criteria are also included in this test report.

1.1 Authorization:

This test report is in partial fulfillment of Contract Number N62269-78-C-0041, and in response to Fluid Power Design Group request.

1.2 <u>Responsibility</u>:

1.2.1 Minimum test criteria indicative of conformance to the intent of this specification were jointly determined by Structural Mechanical Environmental Test Section and Fluid Power Design Engineering Group.

1.2.2 Data acquisition and instrument calibration, where required, was provided by the Data Acquisition Section of the Corporate Instrumentation Dept.

2.0 <u>DESCRIPTION OF TEST ARTICLE</u>:

2.1 <u>General</u> - The overall test article was a hydraulic checkout system installed in the F-14A flight control system simulator. The combined hydraulic system only was used for the testing.

2.2 Integrated Components tested in the F-14A Simulator

2.2.1 Flow Sensors

(a) System Quiescent
(b) Rudder Actuator
(c) Pump Case Drain

2.2.2 (a) System Pressure
(b) Return Pressure
(c) Case Drain Pressure

2.2.3 <u>Reservoir, Combined</u>

(a) Level, measurement calibration, low level
(b) Air in reservoir, excess

2.2.4 Differential Displacement

(a) Rudder and Rudder pedals

2.2.5 Pressure Switch (s)

(a) Low System Pressure
(b) Low Pump Suction Pressure

2.2.6 Hycos Display Panel

(a) System Test
(b) Circuit Test

3.0 TEST LOCATION

All of the testing listed in this Test Report was performed at Grumman Aerospace Corporation facilities in Plant 14, Bethpage, New York.

4.0 COMPONENT TEST RESULTS

4.1 Hydraulic Reservoir - Level sensing unit was tested on bench and F-14A Simulator. (F-14A Combined Reservoir Only)

4.1.1 Set reservoir on bench with level sensing potentiometer setup.

4.1.2 Using nitrogen moved reservoir piston through full stroke measuring stroke from reservoir tape and noting resistance at each inch of travel. Recorded. All readings were within design parameters.

4.1.3 Installed reservoir on simulator and filled with fluid.

4.2 Flow Sensor - Bypass Type

4.2.1 Installed sensor on flow bench with gaging for Δ P and flow measurement.

4.2.2 Starting at 100 psi inlet, increased pressure in 100 psi increments noting ΔP and flow at each increment. Recorded. Noted fluid temperature. Noted button trip points and recorded. Reset. All readings were within design requirements.

4.3 Temperature Compensated Pressure Switch

4.3.1 Bench Test

After a proof test, placed the switch in a temperature control chamber with temperature and pressure hook-ups as necessary to check the switch actuation points. Recorded. The switch trip points were within the manufacturer's limits.

4.4.1 On bench, connected leads to proper terminals, as per print. With the probe immersed in hydraulic oil, increased the temperature until the switch tripped. The switch actuated at the design temperature all three times this test was performed.

4.5 The position potentiometer of the rudder pedal was calibrated as resistance (K ohms) vs. rudder position ($\pm$ 30 degrees). The rudder position pot. was calibrated in the same manner. These two variable resistance values were fed into the HYCOS microprocessor. The two pots. were then installed on the simulator. They were tested by intentionally disconnecting one pot. and noting the malfunction indication on the HYCOS panel, then reconnecting the pot. and eliminating this indication.

4.6.1 Apparatus was connected hydraulically and electrically on the test bench. Applied proper hydraulic pressure and noted delta-pressure and internal switch actuation. All the delta-P indicators actuated at the proper specification value.

4.7.1 With the level sensor installed, physically displaced the accumulator piston. At each one inch displacement measured and recorded the potentiometer resistance. These values were fed into the microprocessor.

4.8 On the HYCOS test panel in the System block, the Circuit Test switch is used to verify operation of the "grain of wheat" bulbs. This is switch position 1. This position also checks the external circuitry from the panel to the discrete pickups on the simulator. Switch position 2 illuminates the bulbs in sequential order to show that the microprocessor is operational. This Circuit Test function operation correctly.

5.0 <u>SYSTEM TEST IN SIMULATOR-TEST PROCEDURES</u>

5.1.1 Ascertained and recorded the baseline case flow using a flow meter installed in the simulator.

5.1.2 Using a hydraulic pressure source, bled flow into the case line until the sensor tripped. This triggered an indicator light on the HYCOS panel. Trip flow was 4.5 GPM which was the proper value. When reset, the panel light extinguished.

5.2.2 Applied external heat to the simulator to obtain a temperature greater than 200°F. This was accomplished with the use of a heat gun in the area of the thermal switch installation within the case drain line. The temperature at which the indicator illuminated on the HYCOS panel was 315°F.

5.3.1 Ascertained and recorded baseline quiescent flow and temperature of the simulator. Temperature was 170°F. and flow was 2.3 GPM.

5.3.2 Increased combined system flow slowly over the baseline rate determined in para. 5.3.1 until the quiescent sensor tripped. This was indicated on the HYCOS panel. System Test switch must be in position #2 for the sensor to trip. Recorded the flowrate and temperature. Trip occurred at a flowrate of 10GPM which is within the specification limits of 12 $\pm$ 2 GPM.

5.4.1 After verifying a normal baseline system pressure, initiated a controlled leak in a pressure line to cause the system pressure to drop below the set value of the HYCOS pressure switch. Recorded the temperature and pressure when the low pressure indicator light came on. Temperature was 165°F. and pressure was 2350 psig. This value of pressure was within the specified tolerances.

5.5.1 Operated the simulator to obtain the baseline temperature at the filter module housing which was adjacent to the relief valve. The baseline temperature was found to be 140°F. A relief valve assembly with an internal leak was then substituted for the normal relief valve assembly. The simulator was again operated and the temperature was observed to increase, due to the excessive relief valve flow, until the thermocouple switch actuated at 320°F. This triggered an indicator light on the HYCOS panel. When the simulator was cooled down the light extinguished upon reset. Note: This switch was set for 320°F. therefore a heat gun was needed to activate the thermal switch.

5.6.1 Operated the simulator and verified the proper functioning of the differential displacement indicators by using rudder inputs of various magnitudes and frequencies. The differential displacement indicator bulbs on the HYCOs panel remained off throughout the entire input sequence. Next, a bolt was carefully removed from the rudder actuator input linkage and the rudder was allowed to move. The panel light now came on with only a very slight relative movement. The linkage was reconnected, which extinghished the light, and caused it to remain off during subsequent rudder pedal movements.

5.7.1 Determined quiescent rudder actuator flow by operating simulator without excessive rudder inputs. Recorded this flow to be 0.8 GPM.

5.7.2 With the simulator running, increased the rudder actuator flow by imparting large rudder pedal inputs so that flow through the flow sensor exceeded the set point of 4.5 $\pm$1 GPM. The system test switch must be in position #2 for the indicator light to trip. Recorded the flow at the point the sensor caused the HYCOS panel light to illuminate. This was at a flow rate of 5.0 GPM, which is within the flow sensor specifications.

5.8.1 The first test was to demonstrate excessive air in the reservoir. This was done by a delta position of the reservoir piston between a shut down and an operating status. If this delta position was over the value programmed into the HYCOs micro-processor the panel light would come on. The oil level in the reservoir is checked by observing the tape indicator before and after start up. Before starting the simulator to check for excessive air in the reservoir the System Test switch must be put in position 1 momentarily. This is necessary to program the starting position of the piston into the microprocessor. After starting the simulator the HYCOS test panel will interogate the system for excessive air in the reservoir only once when the System Test switch is put in the #2 position. IF the panel indicated air, this switch was held on so that the reservoir air bleed valve could be activated to remove the air. The switch was released when the indicator light went off. This test was demonstrated successfully. The delta inches from start up to shut down on the tape was 1.75 inches.

5.8.2 The next reservoir test was designed to indicate a low oil level. After the "air in reservoir" test, and with the simulator running, the visual tape position (6 inches) was noted. Next, approximately one inch of oil was bled off by means of the reservoir bleed valve, whereupon the level indicator light on the panel illuminated. Tape position, 5 inches. Oil was continued to be bled off until the "leak" light on the panel was triggered. Tape position was now 4 inches. Using an external source, the oil reservoir was slowly refilled noting that the "leak" and "level" lights extinguished at the proper oil levels. This test was repeated except the simulator was run to cause the oil temperature to heat up to approximately 150°F. before proceeding. Both lights actuated correctly at the proper oil levels.

5.9.1 The delta P indicator for the pressure line filter was checked by removing the filter element and wrapping steel shim stock around approximately three quarters of its area. The element was reinstalled reinstalled and the simulator was started up. At a point somewhat past quiescent flow and at a pressure of 125 psig, the panel "filter pressure" light was tripped, and the manual reset button on the indicator was extended. With flow at quiescent this button was able to be reset. The System Test switch in position #2 was used to interogate the system. This procedure simulated a contaminated element by producing a larger delta P across the filter than usual. This was a successful test in that the delta P indicator operated within the specification values.

5.9.2 The delta P indicator for the return line filter was tested in the same manner as above and the filter "return" light came on at 110 psig. These values were within the specified tolerances.

5.9.3 The pump case drain filter with the sampling valve was tested per para. 5.9.1 also. The panel indicator light is the "filter" light under pumps, combined section of the panel. This unit is set for 100 $\pm$ 30 psig. The delta P indicator operated at 90 psid and the panel light did come on properly and went off upon reset.

5.10.1 With the simulator not in operation the pneumatic precharge pressure was 500 psig. The system was then interogated by having the System Test switch in position #2. The RAT light did not illuminate in this case. The precharge pressure was slowly bled off to approximately 400 psig and with the switch in position #2 the panel light lit. The accumulator was then recharged to 500 psig and the simulator was put into operation. With the System Test switch in position #2 the panel indicator did not light. When the pneumatic precharge was again bled off, the RAT light on the panel illuminated when interogated. The simulator was then shut down and all hydraulic pressure was totally bled from the accumulator. The residual pneumatic pressure in the accumulator was then recorded and found to be 350 psig. The accumulator was then recharged back to 500 psig and the simulator started again. This time heat was applied to the thermocouple area of the RAT accumulator while the SYstem Test switch was inposition #2. The panel precharge light did not illuminate. The external heat was applied with the use of a heat gun which raised the temperature to approximately 350°F. This test demonstrated that the temperature compensation circuitry of the microprocessor was functioning properly.

5.11.1 With 3000 psig in the pneumatic bottle there was no illumination of the fiber optic readout on the panel. The Circuit Test switch was activated to position #1 and a white illumination was visible in the "liquid" readout. Switched to position #2, System Test, and no illumination of the "liquid" occurred. All the pressure from the pneumatic bottle was relieved and enough water was put into the bottle to cover the gap between the optic fibers probes. The bottle was then repressurized to 300 psig. Selected System Test with switch in position #2 on the panel, and the optic fiber "liquid" readout showed a white illumination. The pressure was then bled off the pneumatic bottle and the water removed. The inside of the bottle was then thoroughly blown dry. This test showed the system worked as designed. This test was done as a bench test.

5.11.2 Para. 5.11.1 was repeated except MIL-H-5606 hydraulic oil was added to the bottle instead of water. The "liquid" readout in this case was illuminated as pink. The pneumatic bottle was then depressurized and all traces of hydraulic oil cleaned out. The bottle was then repressurized and interogated. No illumination appeared at the "liquid" readout on the test panel. These events illustrated proper operation of the system. This test also was done as a bench test.

5.12.1 The desiccant drier readout is located in the reservoir area of the HYCOS panel and is labeled "drier". With the desiccant nonsaturated and the cartridge pressurized to 40 psig the System Test switch was in position #2. The drier readout showed a pale blue illumination. The desiccant cartridge was then depressurized and water added so as to saturate it. The cartridge was reassembled and pressurized to 40 psig. The system was interogated with switch in position #2, System Test. The "drier" optic fiber readout indicated a pink illumination. The desiccant cartridge was pressurized with air. This test demonstrated correct functioning of the optic fibers with the HYCOS panel and was done as a bench test.

CONTRACT REQUIREMENTS	CONTRACT ITEM	MODEL	CONTRACT NO.
		HYCOS	N62269-78-C-0041

REPORT

NO. A51-314-P-72.48 DATE: 27 September 1978

ACCEPTANCE TEST PROCEDURE FOR
TEMPERATURE COMPENSATED PRESSURE SWITCH
MANUFACTURER'S P/N 1500PT89

CODE 26512

PREPARED BY: R. L. Kennedy
R. L. Kennedy

CHECKED BY: W. E. Yearsley 9/27/78
W. E. Yearsley

DEPARTMENT:

SECTION:

TECHNICAL APPROVAL

APPROVED BY: J. Duzich
J. Duzich

APPROVED BY:

APPROVED BY:

REVISIONS

DATE	REV. BY	REVISIONS & ADDED PAGES	REMARKS

GAC 324A REV. 3
10-70

GRUMMAN AEROSPACE CORPORATION

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ACCEPTANCE TEST PROCEDURES FOR
TEMPERATURE COMPENSATED PRESSURE SWITCH
MANUFACTURERS P/N 1500PT89-1 & 2

1.0 VISUAL INSPECTION: Visually inspect unit for dents, severe scratches, faulty threads, faulty welds, severly bent or broken pin connections and properly etched part numbers, serial number, etc.; check for safety wire hole in base (.036" safety wire should fit easily). See Figure 2.

2.0 PROOF PRESSURE TEST

2.1 Using Test Manifold per Figure 1, enclosed in a protective steel box, slowly apply gaseous nitrogen pressure until 5000 psia is reached, lock in this pressure for two minutes and, using a pressure gage, observe for leakage (pressure drop-off). Reduce pressure to zero and repeat test once. Then visually examine switch for distortion, permanent set or any signs of any detremental effects as a result of this proof pressure test.

NOTE: See Figure 3 for method of connecting GN_2 supply for Proof Test.

3.0 ELECTRICAL CHECK AT AMBIENT PRESSURE & TEMPERATURE (0 Psig)

3.1 Continuity Check: use multi-meter or continuity light: see Figure 4

Pin B to Pin C - open
Pin A to Pin B - open
Pin C to Pin A - continuity

3.2 Resistive Check: must be less than 1 amp at 28 VDC. Use continuity lamps 28 VDC approx. 38 ma (Lamp No. 327 or equiv.). If lamps light brightly, resistance is below 1 amp.

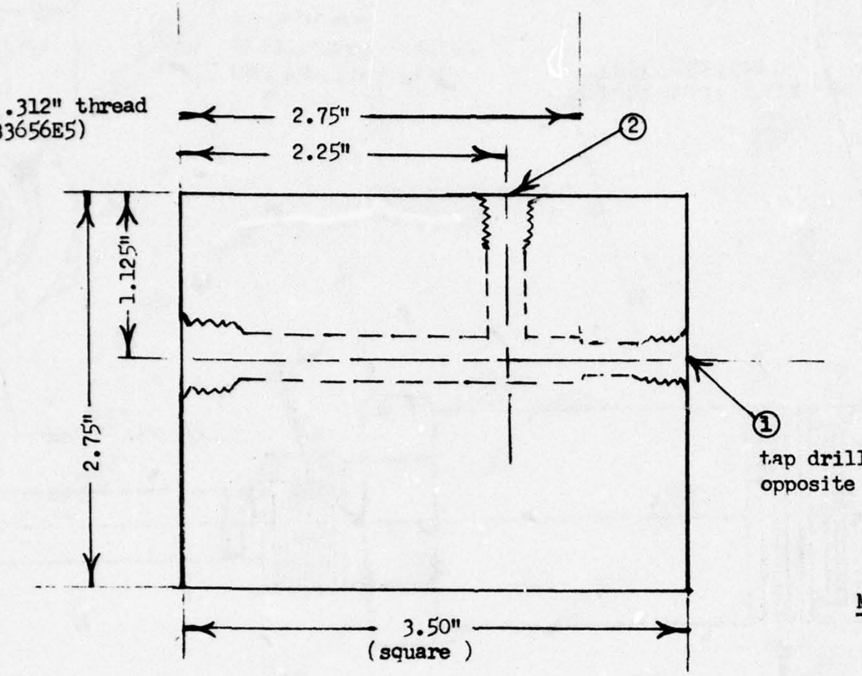
4.0 SWITCH ACTUATION POINTS

Using test manifold connected per Figure 3 and enclosed in a temperature control chamber slowly apply pressure(s) and temperature(s) to verify that the switch actuates within the tolerances specified on the graph(s) of Figure 5.

5.0 POST-TEST EXAMINATION OF PRODUCT

This test consists of repeating the visual inspection of Para. 1.0 to assure no damage has resulted from any of these tests. If no damage is evident and if all the preceeding tests met the specifications, the unit is considered to have passed this Acceptance Test Procedure.

tap drill for .312" thread
2.75" deep (MS33656E5)



tap drill for .25" AN port into
opposite hole at 1 & 2

Mat'l.:
steel, 4130 or equiv.

TEST MANIFOLD - TEMPERATURE COMPENSATED PRESSURE SWITCH - (1 Requ'd.)

FIGURE 1

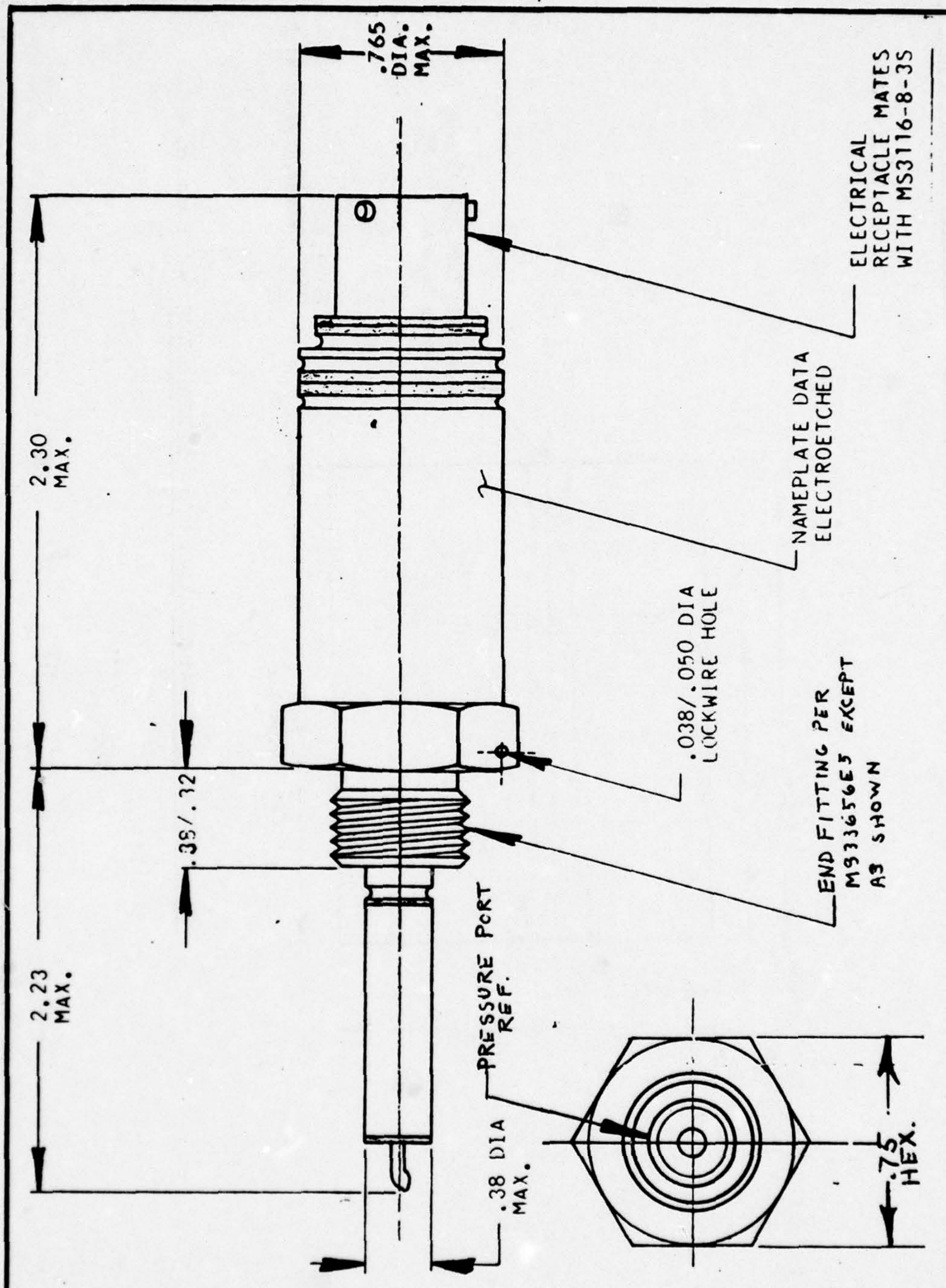
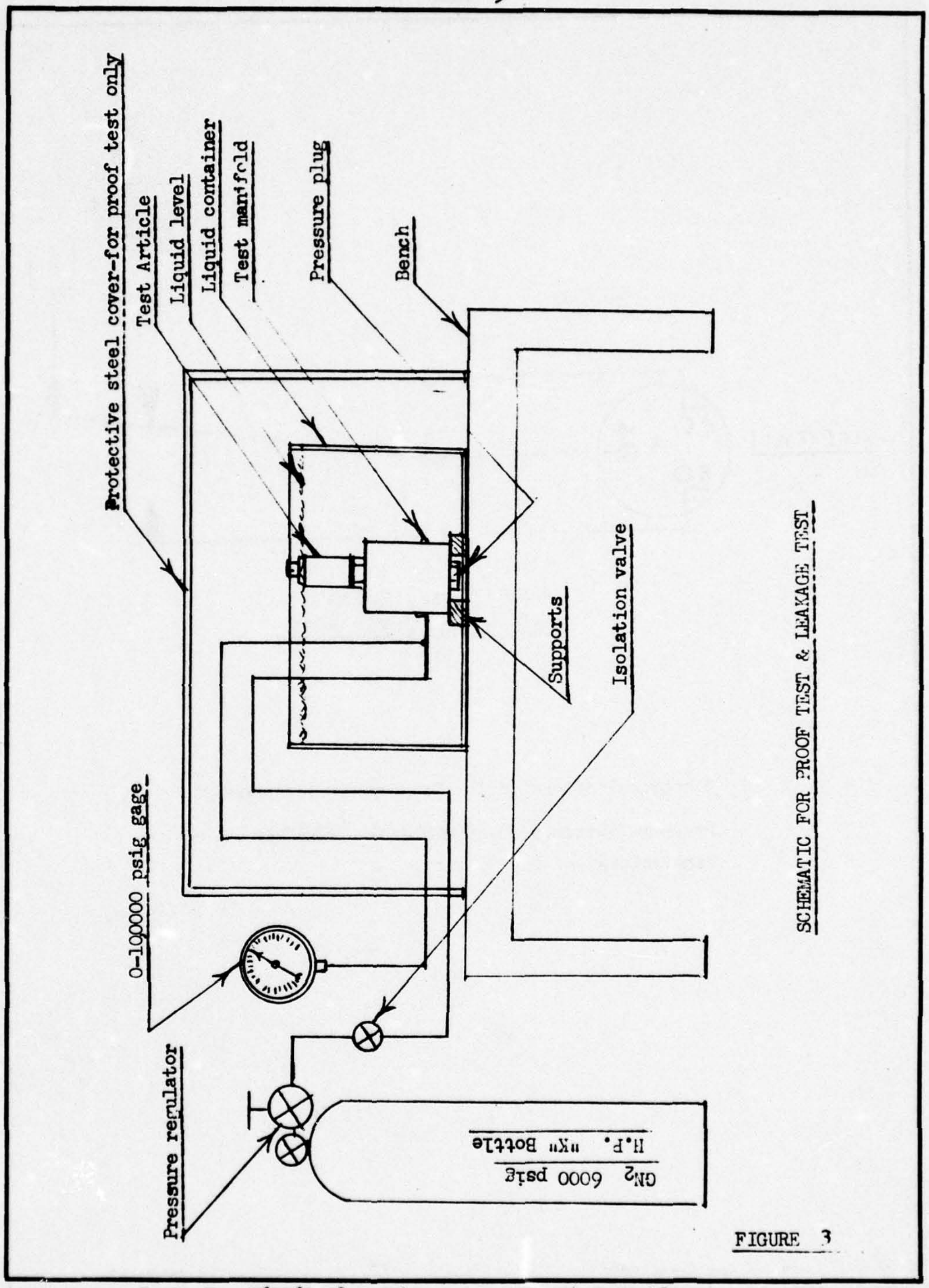
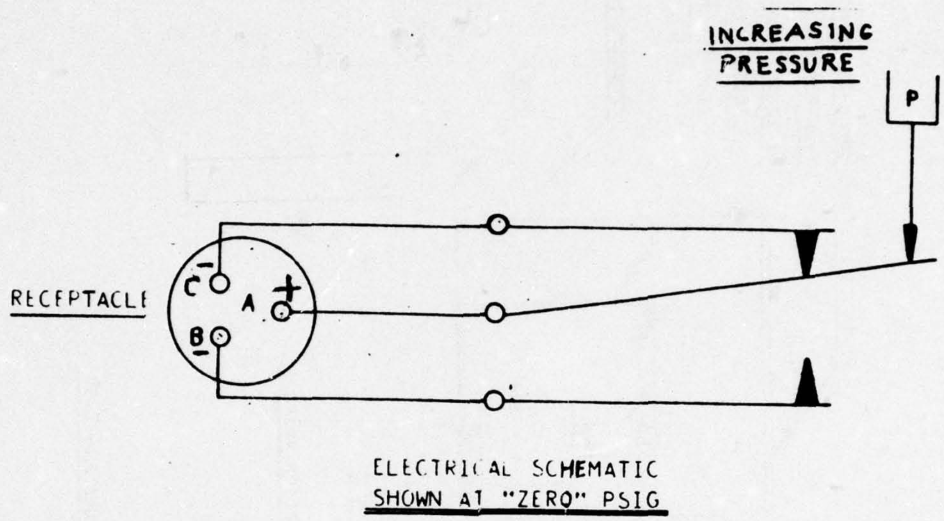

.765 DIA. MAX.
ELECTRICAL RECEPTACLE MATES WITH MS3116-8-3S
NAMEPLATE DATA ELECTROETCHED
2.30 MAX.
.038/.050 DIA LOCKWIRE HOLE
END FITTING PER MS33656E5 EXCEPT AS SHOWN
.39/.32
PRESSURE PORT REF.
2.23 MAX.
.38 DIA MAX.
.75 HEX.

FIGURE 2



SCHEMATIC FOR PROOF TEST & LEAKAGE TEST

FIGURE 3



Electrical schematic for Temperature Compensated

Pressure Switch(s) part numbers: 1500PT89-1 & -2 .

Manufactured by Neo-Dyn, Inc.

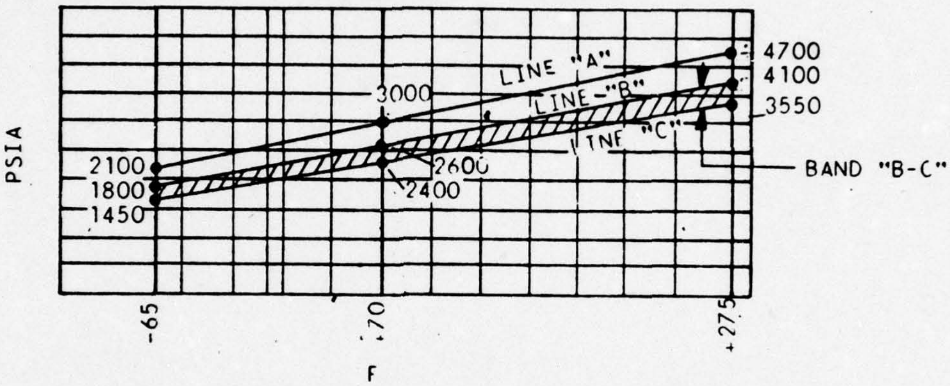
FIGURE 4

SPECIFICATIONS

ACTUATION POINTS (SEE APPLICABLE GRAPH

INCREASING PRESSURE: BY "A" MAX.
DECREASING PRESSURE: WITHIN BAND "B-C"

1500PT89-1



1500PT89-2

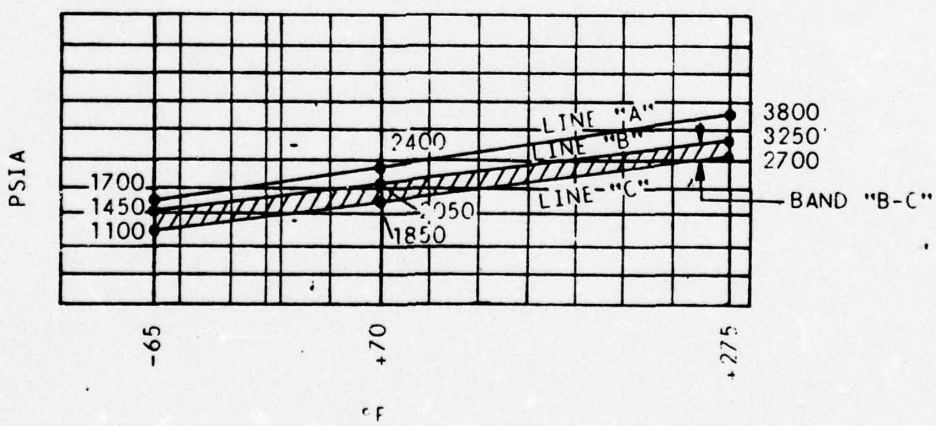


FIGURE 5

APPENDIX B

HYCOS TEST PANEL

ACCEPTANCE TEST PROCEDURE

DESCRIPTION

The HYCOS test panel is a device used to checkout operation of the HYCOS display panel before installation in the aircraft.

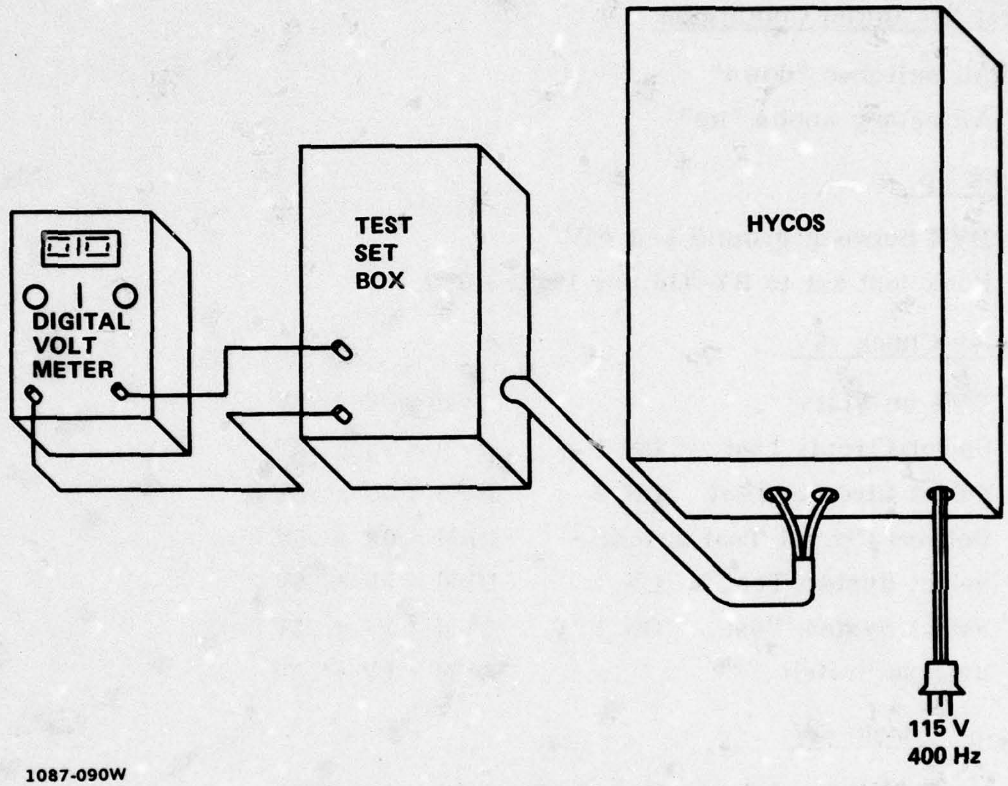


Figure B-1. HYCOS test setup.

A. Required Items

1. HYCOS - HYCOS Test Panel
2. Test Box
3. DVM - Digital Voltmeter

B. Test Set Initial Conditions

1. All switches "down"
2. All rotary knobs "up"

C. Hook Up

1. DVM between ground and +5V
2. Hook test set to HYCOS per Figure B-1

D. Power Check +5V

1. DVM on Volts		DVM = 0V ± .5V
2. Select Circuit Test	ON 1	DVM = 5V ± .5V
3. Select Circuits Test	ON 2	DVM = 5V ± .5V
4. Release Circuit Test switch		DVM = 0V ± .5V
5. Select System Test	ON 1	DVM = 5V ± .5V
6. Select System Test	ON 2	DVM = 5V ± .5V
7. Release Switch		DVM = 5V + .5V

E. Power Check -5V

1. Move DVM Lead from +5V to -5V	DVM = 0 ± .5V
2. Throw Circuit Test to ON 1	DVM = -5V ± .5V
3. Throw Circuit Test to ON 2	DVM = -5V ± .5V
4. Release Circuit Test switch	DVM = 0V ± .5V
5. Throw System Test to ON 1	DVM = -5 ± .5V
6. Throw System Test to ON 2	DVM = -5V ± .5V
7. Release switch	DVM = 0V ± .5V

F. Power Check +5V Switch

1. Move DVM lead from -5V to +5V SW		DVM = 0V ± .5V
2. Select Circuit Test	ON 1	DVM = 0V ± .5V
3. Select Circuit Test	ON 2	DVM = 0V ± 5V
4. Release Circuit Test switch		DVM = 0V ± 5V
5. Select System Test	ON 1	DVM = 0V ± 5V

6.	Select System Test	ON 2	DVM = 0V ± 5V
7.	Release switch		DVM = 0V ± 5V
8.	Select Hydraulic switch on test set-up		DVM = 0V ± 5V
9.	Select Circuit Test	ON 1	DVM = 5V ± .5V
10.	Select Circuit Test	ON 2	DVM = 5V ± .5V
11.	Release Circuit Test switch		DVM = 0V ± .5V
12.	Select Hydraulic switch on test set-down		DVM = 0V ± .5V
13.	Select System Test	ON 1	DVM = 5V ± .5V
14.	Select System Test	ON 2	DVM = 5V ± .5V
15.	Release switch		DVM = 0V ± .5V

G. Lamp Test

1.	Select Circuit Test	ON 1	All Red cap lamps lit
2.	Select Circuit Test	ON 2	All red cap lamps light in sequence by groups
3.	Release Circuit Test		All lamps out
4.	System Test to ON 1		All lamps out
5.	System Test to ON 2		All lamps out

H. System Test Static Operation

1.	The following switches "up" on Test Set PUMP - CASE, FILT, TEMP, BACKUP FILTER - PRESS, RETRN PNEU PRESS - CANOPY, GEAR RELIEF VALVE		All lamps out - Lamps lit
2.	Select System Test	ON 1	Pumps CASE Pumps FILT Pumps TEMP Pumps BACKUP Filters PRESS Filters Return Pneu Press Canopy Pneu Press Gear Relief Valve
3.	Select System Test	ON 2	Same Lamps Lit

4. Release System Test switch	All lamps out
5. Return all switches on Test Set to former position	No lamps lit
6. Select following switches to "up" position QUIESCENT FLOW SYSTEM QUIESCENT FLOW RUDDER PUMPS-PRESS	No lamps lit
7. Select System Test ON 1	No lamps lit
8. Select System Test ON 2	No lamps lit
9. Release switch	No lamps lit
10. Select Hydraulic switch on test set "up" position	No lamps lit
11. Select System Test ON 1	3 corresponding lamps lit
12. Select System Test ON 2	3 corresponding lamps lit
13. Release System Test switch	No lamps lit
14. Return all switches on Test Set to former positions	No lamps lit

I. DIFF DISP TEST

1. Set ROD 1 to FAIL 1	
2. Select System Test ON 2	Rudder lamp - On
3. Hold System Test switch in ON 2 move RUD 2 to FAIL 1	Rudder lamp - Out
4. Return RUD 1 to NORMAL System Test switch still ON 2	Rudder lamp - On
5. Move RUD 2 back to NORMAL System Test switch still ON 2	Rudder lamp - Off
6. Move RUD 2 to FAIL 2 System Test switch still ON 2	Rudder lamp On
7. Move RUD 1 to FAIL 2 System Test switch still ON 2	Rudder lamp Off
8. Return RUD 2 to NORMAL System Test switch still ON 2	Rudder lamp On
9. Return RUD 1 to NORMAL System Test switch still ON 2	Rudder lamp Off
10. Release System Test switch	

J. Accum Prechange RAT Test

1. Set RAT TEMP to FAIL 1 - Press System Test ON 2	RAT Lamp ON
2. Return RAT TEMP to NORMAL Press System Test ON 2	RAT Lamp Off
3. Set RAT PRESS to FAIL 1 Press System Test ON 2	RAT Lamp On
4. Return RAT PRESS to NORMAL Press System Test ON 2	RAT Lamp Off
5. Set RAT DISP to FAIL 1 Press System Test to ON 2	RAT Lamp ON
6. Return RAT DISP to NORMAL	RAT Lamp OFF

K. Reservoir Air Test

1. System Test to ON 1	
2. Release switch	
3. Set RESERVOIR DISP Pot. to Air	
4. System Test switch to ON 2	Air Lamp not On
5. Return RESERVOIR DISP Pot. to NORMAL	
6. System Test to ON 1 & Release	
7. Set RESERVOIR DISP Pot. to Air	
8. Set Hydraulic switch on Test Set to ON	
9. System Test switch to ON 2	Air Lamp On
10. Release System Test switch	
11. Return DISP Pot. to NORMAL	

L. Reservoir Temp Test

1. Set TEMP Pot. to FAIL	
2. Press System Test switch ON 2	Temp Lamp On
3. Return TEMP Pot. slowly toward NORMAL with System Test switch held on. Lamp should go out before reaching NORMAL. Stop Pot. at NORMAL	

M. <u>Reservoir Level and Leak Test</u>

1. Set DISPL Pot. to LEVEL	
2. Press System Test switch to ON 2	Level lamp on
3. Release System Test switch	
4. Set TEMP Pot. to LEVEL	
5. Press System Test switch to ON 2	Level lamp OFF
6. While holding System Test, set ON 2, return TEMP Pot. to NORMAL	
7. Release System Test switch	
8. Set DISPL Pot. to LEAK	
9. Press System Test switch	Level lamp ON Leak lamp ON
10. With System Test held on, slowly turn TEMP Pot. at LEAK	First Leak lamp off First level on both lamps OFF
11. Release System Test switch	
12. Return DISPL and TEMP pots to NORMAL	

APPENDIX C

GLOSSARY OF TERMS

MOS - Metal Oxide Semiconductor. A semiconductor manufacturing technology used to produce IC logic components. A class of insulated gate field effect transistors

E. PROM - Erasable programmable read only memory

ROM - Read Only Memory. A memory in which information is stored permanently

BIT - A Binary Digit. A Bit can have a value of either 0 or 1

CPU - Central Processing Unit. That part of the computer system that can control the interpretation and execution of instructions

RAM - Random Access Memory. A RAM is a read-write memory. Each Bit of information is stored or retrieved in the same amount of time as any other BIT

BYTE - The number of Bits that a computer processes as a unit, usually 8

I/O - Input Output. General term for the equipment used to communicate with a computer CPU, or the data involved in that communication

LED - Light Emitting Diode. A semiconductor device which emits light when current passes through it

A/D CONVERTER - A unit or device that converts an analog signal; that is, a signal in the form of a continuously variable voltage or current, to a digital signal; a series of Bits

CMOS - Complementary Metal Oxide Semiconductor. A term used to describe an IC logic family. CMOS logic family has very low power dissipation, low current density per chip, and moderate speed of operation

LAMP DRIVER - A device used to amplify a weak signal in order to provide enough current to drive lamps

BUS - A group of wires that allows memory, CPU, and I/O devices to exchange information

LCD - Liquid Crystal Display

BUFFER - A storage device in which data is stored temporarily during data transfers

HEX BUS DRIVER - An electronic device which contains six amplifiers. Each accepts a small input signal and delivers a larger output signal, with each signal isolated from the other

COUNTER LATCH - Used on LED digital displays. It counts events for discrete time periods, stores the results, and drives a seven-segment LED display

TRANSISTOR - A tiny chip of crystaline material, usually silicon, that amplifies or switches electric current. It is usually a three-terminal semiconductor device

DIODE - A semiconductor device which permits current flow in a single direction. It usually has two terminals

FIBER OPTICS - A way of transmitting light or images through a transparent glass or plastic. Two basic types are coherent fibers, which transmit aligned images (i.e., alphanumeric at output face), and incoherent fibers, which transmit only light. The fiber has a clad coating which reflects the light ray internally

FOOT-LAMBERT - A unit measure of brightness (emitted or reflected light of 1 lumen per square foot)

ACCEPTANCE ANGLE - Angle at which a fiber will accept a light ray, measured from its longitudinal axis

CLADDING - A covering or coating of transparent fiber which reflects light rays internally in a zig-zag fashion along its length. The refractive index of the cladding material is less than that of the core

REFRACTIVE INDEX - The ratio of light velocity in a vacuum to the velocity of light in a given gas, fluid, or transparent solid

NUMERICAL APERATURE - A value that determines the effectiveness of light absorption of a fiber. It is expressed as $N.A. = \left(N^2_{(core)} - N^2_{(clad)}\right)^{\frac{1}{2}}$, where N = refractive index

ACCEPTANCE CONE - A cone perpendicular to an optical fiber face whose included angle is twice the acceptance angle

CRITICAL ANGLE - The angle a light ray travels within a fiber conduit beyond which light is lost within the fiber

Appendix D

PARTICIPATING FIRMS

Aircraft Porous Media	Glen Cove, N.Y.
Walter Kidde & Company	Belleville, N.J.
Clairex Electronics	Mount Vernon, N.Y.
Valtec	West Boyleston, Mass.
Sigma-Netics	Mountain Lakes, N.J.
Sprague Engineering Corporation	Gardena, California
Bourns Incorporated	Riverside, California
Neo-Dyn Inc.	Chatsworth, California
De Laval Special Products Division	Cleveland, Ohio
Abex Corporation	Oxnard, California
Entran Devices	Little Falls, N.J.
Analog Devices	Norwood, Massachusetts
Frisby Airborne Hydraulics	Freeport, N.Y.
E.I. du Pont de Nemours	Wilmington, Delaware
Indiana General	Valparaiso, Indiana
Intel Corporation	Santa Clara, California
Texas Instruments	Attleboro, Mass.
Hunter Spring Division of Ametek	Hatfield, PA
Russel Associates	Bay Shore, N.Y.
Indiana General Magnetic Products	Valparaiso, Indiana
National Semiconductor	Santa Clara, CA
Sprague Electric	Concord, New Hampshire
Telcon Systems Inc	Arlington, Virginia

PARTICIPATING FIRMS (CONT)

Kulite Semiconductor Products . . . . Ridgefield, N.J.

Sealectro Corporation . . . . Mamaroneck, N.Y.

Texas Instruments Corporation . . . . Dallas, Texas

Special Thanks to:

Naval Ocean Systems Center . . . . San Diego, California

APPENDIX E

PAGE 1 OF

CONTRACT REQUIREMENTS	CONTRACT ITEM	MODEL	CONTRACT NO.
		HYCOS	N62269-78-C-0041

REPORT

NO. A51-314-P-72.50 DATE: 12 October 1978

DEVELOPMENT TEST PLAN FOR HYCOS SYSTEM
UTILIZING THE F-14A FLIGHT CONTROLS SIMULATOR
AND COMPONENT TESTING

CODE 26512

PREPARED BY: R. L. Kennedy
R. L. Kennedy

CHECKED BY: W. Yearsley
W. Yearsley

DEPARTMENT:

SECTION: Struct./Mech./Envir./Test Section

TECHNICAL APPROVAL: John J. Duzich
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APPROVED BY: E. C. Anderson
E. Anderson

APPROVED BY:

APPROVED BY: D.O. Bagwell
D. O. Bagwell
Naval Air Development Center

REVISIONS

DATE	REV. BY	REVISIONS & ADDED PAGES	REMARKS

GAC 324A REV. 3
10-70

GRUMMAN AEROSPACE CORPORATION

1087-092W(1)

TABLE OF CONTENTS

1.0 INTRODUCTION: This document is intended to outline developmental testing of the "HYCOS" checkout system as installed in the F-14A Flight Control System Simulator and to demonstrate its suitability for use in an aircraft. Component testing and criteria are also included in this test plan.

1.1 Authorization:

This test program is in partial fulfillment of Contract Number N62269-78-C-0041, and in response to Fluid Power Design Group request for testing.

1.2 Responsibility:

1.2.1 Minimum test criteria indicative of conformance to the intent of this specification have been jointly determined by Structural Mechanical Environmental Test Section and Fluid Power Design Engineering Group; test criteria indicative of conformance of to design criteria have been determined by the cognizant design engineer.

1.2.2 Conduct of the tests, including order of testing, test data reduction; and preparation of the test report, will be the responsibility of the test engineer.

1.2.3 Data aquisition and instrument calibration, where required, will be provided by the Data Aquisition Section of the Corporate Instrumentation Dept.

2.0 DESCRIPTION OF TEST ARTICLE

2.1 General- The overall test article is a hydraulic checkout system installed in the F-14A flight control system simulator. The combined hydraulic system only is used for the testing of the test article.

2.2 Integrated Components to be tested in the F-14A Simulator

2.2.1 Flow Sensors

(a) System Quiescent
(b) Rudder Actuator
(c) Pump Case Drain

2.2.2 Differential Pressure Indicator

(a) System Pressure
(b) Return Pressure
(c) Case Drain Pressure

2.2.3 Reservoir, Combined

(a) Level, measurement calibration, low level
(b) Air in reservoir, excess

2.2.4 Differential Displacement

(a) Rudder and Rudder pedals

2.2.5 Pressure Switch(s)

(a) Low System Pressure
(b) Low Pump Suction Pressure

2.2.6 Hycos Display Panel

(a) System Test
(b) Circuit Test

3.0 TEST LOCATION

All of the testing listed in this Test Plan will be performed at Grumman Aerospace Corporation facilities in Plant 14, Bethpage, New York.

4.0 COMPONENT TEST PROCEDURES

4.1 Hydraulic Reservoir- Level sensing unit to be tested on bench and F-14A simulator. (F-14A Combined Reservoir Only)

4.1.1 Set reservoir on bench with level sensing potentiometer setup.

4.1.2 Using nitrogen move reservoir piston through full stroke measuring stroke from reservoir tape and noting resistance at each inch of travel. Record.

4.1.3 Install reservoir on simulator and fill with fluid.

4.2 Flow Sensor-Bypass Type

4.2.1 Install sensor on flow bench with gaging for Δ P and flow measurement.

4.2.2 Starting at 100 psi inlet, increase pressure in 100 psi increments noting P and flow at each increment. Record. Note fluid temperature. Note button trip points and record. Reset.

4.3 Temperature Compensated Pressure Switch

4.3.1 Bench Test

After a proof test, put the switch in a temperature control chamber with temperature and pressure hook-ups as necessary to check the swhich actuation points. Record.

4.4 Thermal Switch-Immersion Type

4.4.1 Bench Test: On bench, connect leads to proper terminals, as per print. Increase temperature until switch trips. Repeat three times. (Have the probe immersed in hydraulic oil). Record.

4.5 Rudder Differential Displacement

The position potentiometer on rudder pedal is calibrated pot. resistance (K ohms) vs. rudder position (±30°). The rudder position potentiometer is calibrated in the same manner. These two resistance values are fed to the Hycos microprocessor.

4.6 Filter Delta Δ P Indicator

4.6.1 Bench Test: Connect hydraulically and electrically on a test bench to be able to apply proper hydraulic pressure and read-out delta-pressure and internal switch actuator. Record.

4.7 Accumulator Level Sensing

4.7.1 Bench Test: With level sensor installed, physically displace accumulator piston and at each one inch displacement measure potentiometer resistance. Record.

4.8 Hycos Panel Circuit Test-Function

On the Hycos test panel in the System block, the Circuit Test switch is used to verify operation of the "grain of wheat" bulbs. Switch position on 1 does this. The on 2 switch position illuminates the bulbs in sequential order to show that the micro processor is operational. Switch position on 1 also checks the external circuitry from the panel to the discrete pickups on the simulator.

5.0 SYSTEM TESTS IN SIMULATOR-TEST PROCEDURES

5.1 Excessive Pump Case Drain Flows-

5.1.1 Ascertain baseline case flow using flow meter installed in simulator. Record.

5.1.2 Using a hydraulic press. source bleed flow into case line until sensor trips. Record flow and indicator on HYCOS panel. Trip flow should be 4.5 ± 1 GPM. Reset, and panel light should extinguish.

5.2 Excessive Pump Case Temperature

5.2.1 Ascertain baseline case temperature by using instrumentation normally installed on simulator. Record.

5.2.2 Apply external heat after running simulator to approximately 200°F. Record temperature when indicator on HYCOS panel illuminates. Should be 310°F ± 10°F. (Apply the external heat using a heat gun in the area of the thermal switch installation in the case drain line).

5.3 <u>Excessive System Quiescent Flow</u>

5.3.1 Ascertain baseline quiescent flow with flowmeter mounted in simulator. Record. Note baseline temperature.

5.3.2 Increase combined system flow slowly over the baseline rate determined in para. 5.3.1 until the quiescent flow sensor trips. Note and record flow and temperature. Trip should occur at 12 ± 2 GPM. Note indication on HYCOS panel. System Test #2 must be on for the sensor to trip. Reset.

5.4 <u>Low System Pressure</u>

5.4.1 After verifying a normal baseline system pressure, initiate a controlled leak in a pressure line to cause the system pressure to drip below the set value of the HYCOS system pressure switch. Record the pressure and temperature when the panel low pressure indicator light comes on. Pressure should be 2250 psig ± 100 psig.

5.5 <u>High Temperature- Relief Valve Operation</u>

5.5.1 Operate the simulator to obtain the baseline temperature at the filter module housing adjacent to the relief valve. Next substitute a relief valve assembly with an internal leak in it for the normal relief valve assembly. Operate the simulator again and allow the temperature to increase, due to the excessive relief valve flow, until the thermocouple switch actuates. Record this temperature. NOTE: Panel light on. Cool down; light should extinguish upon reset.

5.6.1 Operate simulator and verify proper functioning of differential displacement indication by rudder pedal inputs of various magnitudes and frequencies. The differential displacement indicator bulb on the HYCOS panel should not come on. Next, carefully remove a bolt from the rudder actuator input linkage and allow the rudder to move. The panel light should come on. Reconnect the linkage and the light should extinguish.

5.7 <u>Excessive Rudder Actuator Quiescent Flow</u>

5.7.1 Determine quiescent rudder actuator flow by operating simulator without excessive rudder inputs. Record this flow.

5.7.2 With the simulator running, increase the rudder actuator flow by imparting large rudder pedal inputs so that the flow through the flow sensor will exceed the set point of 4.5 ± 1 GPM. The system test position 2 must be selected on the HYCOS panel to

trip. Record the flow at the point the sensor causes the HYCOS panel light to come on.

5.8 Hydraulic Reservoir- Combined

5.8.1 The first test is to demonstrate excessive air in the reservoir. This is done by a delta position of the reservoir piston between a shut down and an operating status. If this delta position is over the value programmed into the Hycos micro-processor the panel light will come on. The oil level in the reservoir can be checked by observing the tape indicator before and after start up. Before starting the simulator to check for excessive air in the reservoir put the "System Test" switch to the "on 1" position momentarily. This is necessary to program the piston starting position in the micro-processor. After starting the simulator the Hycos Test Panel will interogate the system for excessive air in the reservoir only once when the System Test switch is put in the "on 2" position. This switch should be held on if the panel indicates "air" so that the reservoir air bleed valve can be activated to remove the air. The switch can be released when the light goes off.

5.8.2 The next reservoir test is a "level" light designed to indicate a low oil level. After the air in reservoir test and with the simulator running note the visual tape position. Next bleed off approximately one inch of oil by means of the reservoir bleed valve whereupon the "level" indicator light on the panel should light. Continue bleeding off oil for approximately one more inch until the "leak" light on the panel lights. Next, using an external source, slowly refill the reservoir noting the panel leak and level lights extinguish. Repeat this test except run simulator to cause the oil temperature to heat up to approximately 150°F first.

5.9 Differential Pressure Indicator- Filters

5.9.1 The pressure line filter delta P indicator can be checked by removing the filter element and wrapping steel shim stock around it to cover approximately three quarters of the area. Reinstall the element and start up the simulator. The panel filter-pressure light should come on at a flow somewhat greater than quiescent and a pressure of 100 psig ± 30 psig. The manual reset buttons on the indicator should extend also. With flow at quiescent this button should be able to be reset. The System Test "on 2" switch must be used to interogate the system. This procedure simulates a contaminated element by a greater delta P across the element.

5.9.2 The return line filter delta P indicator can be tested in the same manner as above and the filter return light should come on at 100 psig ± 30 psig.

5.9.3 The pump case drain filter with the sampling valve can be tested per para. 5.9.1. The panel indicator light is the filter light under pumps, combined, section of the panel. This unit is set for 100 ± 30 psig.

5.10 Accumulator - Ram Air Turbine (RAT)

5.10.1 With the simulator not operating note that the pneumatic precharge pressure is 500 psig. Interogate the system by switching to system test on 2. The RAT light should not illuminate. Bleed off the precharge pressure slowly to approximately 400 psig and note that the panel light illuminates (with system test on 2). Recharge the accumulator to 500 psig and then operate the simulator. The panel light should not illuminate when interogated (system test on 2). Bleed off the pneumatic precharge again and note that the RAT light on the panel illuminates when interogated. Shut down the simulator and totally bleed the hydraulic pressure from the accumulator. Record the pneumatic pressure in the accumulator. This residual pneumatic pressure should be 400 psig or less. Recharge the accumulator to 500 psig again. Start up the simulator again and apply heat to the area of the accumulator near the thermocouple while the system test switch is in the on 2 position. The panel precharge light should not illuminate. Use a heat gun for this test and apply approximately 350°F of external temperature to the thermocouple area of the RAT accumulator. This test will demonstrate that the temperature compensation circuitry of the micro processor is functioning properly.

5.11 High Pressure Pneumatic Bottle Liquid Detection

5.11.1 With 3000 psig in the pneumatic bottle there should be no illumination of the fiber optic readout on the panel. Activate the circuit test switch to on 1 and a white illumination should be visible on the "liquid" readout. Switch to system test on 2 and no illumination of the optic readout "liquid" should occur The simulator should be operated for this test. Shut down the simulator. Relieve all the pressure from the pneumatic bottle and put enough water into the bottle to cover the gap between the fiberoptic probes. Repressurize the bottle to 3000 psig and start the simulator. Select system test on 2 switch position on the panel and the fiber optic readout "liquid" should show a white illumination. Shutdown the simulator, bleed off the pressure from the pneumatic bottle and remove the water. Blow dry the inside of the bottle thoroughly.

5.11.2 Repeat para. 5.11.1 except add MIL-H-5606 hydraulic oil to bottle in place of water. The "liquid" readout on the panel should illuminate as a pink or red. Shutdown the simulator, depressurize the pneumatic bottle and clean out all traces of the hydraulic oil. Reinstall and repressurize the pneumatic bottle. Start the simulator and interogate the "liquid" readout on the test panel. No illumination should appear at the "liquid" readout.

5.12 **Desiccant Saturation** - Detection

5.12.1 The desiccant drier is readout in the reservoir area of the HYCOS panel and is labeled "drier". With the desiccant non-saturated and the cartridge pressurized to 40 psig select system test switch to 2 position with the simulator operating. The drier readout should show a pale blue illumination. Shut down the simulator, depressurize the desiccant cartridge and add water to the desiccant so as to saturate it. Reassemble the cartridge, pressurize it to 40 psig and restart the simulator. Interrograte the system test on switch position 2. The drier fiber optie readout should indicate a pink illumination. The desiccant cartridge is pressurized with air.

APPENDIX F

SPECIFICATIONS

In order to define the specific requirements of each major component, broad-based specifications were generated. Individual suppliers were contacted with respect to providing acceptable hardware. In some cases, modifications or revisions were required when dictated during acceptance testing. A list of the specifications and the specifications themselves appear in this appendix.

SPECIFICATIONS INDEX

SPECIFICATION	NUMBER
Thermal Switch, Manually Resettable	201
Differential Pressure Indicator, Filter	202
Flow Sensor, Bypass Type	203
Pressure Switch, Temperature Compensated	204
Moisture Indicator, Visual Type	205
Cable, Fiber Optic	206
Transformer, Linear Variable Differential	207
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Potentiometer, Rotary	209
Temperature Probe, Analog Output	210
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Photo Diode, Large Area Silicone	212
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Switch, Pressure	214
Linear Transducer Position	215
Motor, Mechanical	216

1087-098(1)W

Specification 201
(13 January 1978)

GRUMMAN AEROSPACE CORPORATION
Bethpage, N. Y. 11714
HYCOS II

Specification: Thermal Switch, Manually Resettable

Purpose: The thermal switch is used in an airborne hydraulic system to indicate an over temperature condition. Once actuated, the thermal switch must be manually reset. When actuation occurs, a visual flag appears on the switch body. In addition, electrical continuity occurs thru a single pole double throw sub miniature micro switch. Resetting the manual flag also resets the electrical circuit. The switch probe operates in direct contact with the hydraulic fluid or component surface.

Design Requirements:

Actuation Point:

Increasing Temperature	$300 \begin{smallmatrix}+20\\-0\end{smallmatrix}$ °F
Decreasing Temperature	Manually Reset

Fluid: MIL-H-5606/MIL-H-83282

Fluid: Ambient Temperature

Normal operating -65°F to 275°F

Pressure Rating: (Immersion probe type)

Operating	200 psi
Proof	1500 psi
Burst	3000 psi minimum

Switch Electrical Rating:

10 Amps Resistive at 28VDC

Single pole double throw sub-miniature switch or equivalent

Connector: Electrical receptacle to mate MS27473P8895 plug or provisions for attaching thereto.

Physical Properties:

Diameter: 1.30" max.

Length: 4.53" max.

Interface: MS33656E6 with 0.75 hex. (probe type)
Bracket mounting two .156 holes on 1.813 centers

Weight: 5 oz. max.

Switch chamber: Hermetically sealed

Cycle Life: Mechanical & Electrical - 100,000 minimum

Body hex shall be capable of taking normal boss sealing torque without distortion or setting change.

Specification 202
(13 January 1978)

GRUMMAN AEROSPACE CORPORATION

Bethpage, N. Y. 11714

HYCOS Φ II

Specification: Differential Pressure Indicator, Filter

Purpose:

The differential pressure indicator is a unit mounted to the head of a filter assembly. Its purpose is to indicate a contaminated filter element condition. A temperature sensitive bi-metallic leaf prevents actuation at low fluid temperatures.

For remote readout a three-pin electrical connector is provided as an integral part of the filter assembly. Resetting the indicator button also resets the electrical circuit.

A second version of the indicator incorporates a miniature fluid sampling valve for sampling up-stream fluid under dynamic conditions. Removing the connector shuts off the flow from the sampling valve.

Design Requirements:

Size: The indicator assembly shall fit in the cavity of existing filter assemblies utilized by Grumman. It shall be totally interchangeable.

Operating Temperatures:

Ambient	-65°F to 275°F
Fluid	-65°F to 275°F
Lockout	(a) 100 $^{+15}_{-0}$°F
	(b) 135 $^{+15}_{-0}$°F

Operating Pressures:

Normal	3000 psi
Proof	4500 psi
Burst	7500 psi minimum

Fluid: MIL-H-5606 or MIL-H-83282

Switch Electrical Rating:

10 Amp resistive at 28 VDC
Single pole double throw subminiature

Connector: Electrical receptacle to mate with MS27473P8895 plug

Specification 202

Physical Properties:

A. The indicator shall fit the cavity shown below:

B. Weight: oz. maximum

C. Cycle Life: Mechanical or electrical - 50,000 minimum

Sampling Rate: The sampling valve shall be capable of providing 50 to 80 scc per minute with a psi pressure drop at 50 to 200 °F.

Identification:

Part Number	Electrical Connector	Upstream Sampling Valve
202-1	Yes	No
202-2	Yes	Yes

Reliability

The indicator shall not be affected by residual entraped hydraulic oil, salt spray residue or extrinsic contamination.

4

AP Indicator IDENTIFICATION

Basic Number

202

Suffix "A"

No sampling valve

Suffix "B"

Sampling valve

Suffix **-1** - Thermal unlock at 135 ± 11°F

-2 - Thermal unlock at 100 ± 10°F

Suffix **-10** - Actuates at 90 ± 10 psid

-20 - Actuates at 70 ± 10 psid

Example:

202 - A - 2 - 20

- 20 — Indicator actuates at 70 ± 10 psid
- 2 — Indicator has thermal lockout at 100 ± 10°F
- A — No sampling valves
- 202 — Differential pressure indicator

TABLE I

GRUMMAN AEROSPACE CORPORATION

Bethpage, N. Y. 11714

HYCOS ϕ II

Specification: Flow Sensor, Bypass Type

Purpose:

The flow sensor is an inline device for indicating visually and electrically when a predetermined flow has been exceeded in a particular component or subsystem.

Design Requirements

Each unit shall meet all the design requirements listed below:

Size: The flow sensor shall fit within the envelope specified in Table I.

Performance: Each flow sensor shall meet the performance requirements specified in Table II under operating pressures and temperatures specified below.

Operating Temperature Range:

The operating temperature range of the component is -65°F to 275°F for both fluid and ambient conditions.

Operating Pressures:

Normal	50 to 3000 psi
Proof	4500 psi
Burst	7500 psi

Fail Safe Requirements:

The component shall be so designed that in the unlikely event an internal detail part fails, it shall not cause flow blockage or contribute debris to the system.

Fluid: The unit shall operate with MIL-H-5606 or MIL-H-83282.

Bypass:

All flow sensors shall incorporate a bypass (SHUNT) to handle normal component or system flow without indicator actuation.

Indicator Thermal Lock Out

Each flow sensor mechanical indicator shall have a thermal lock out, which unlocks at 100°±10°F fluid temperature.

Indicator Actuation:

Flow sensors fall into two categories:

Category "A" - Units incorporate provisions for preventing indicator actuation under normal system or component flow conditions. When commanded, these sensors provide information under specific operating conditions.

Category "B" - Units do not see wide variations of flow conditions and indicate when a specific value is exceeded under all operating conditions.

When the visual indicator is reset on both types, the electrical portion shall so indicate.

Mounting Provisions:

Mounting provisions shall be provided capable of taking full tubing installation torque without structural failure.

Ports: Ports shall be in accordance with MS33649 for both ends. The use of MS33649 and MS33656 on one sensor is acceptable for murphy proofing.

Connector: The electrical connector shall be in accordance with MS3112E8-3P.

Weight: The dry weight of each component shall not exceed that specified in Table II.

TABLE I

Preliminary Envelope

Part Number	MAXIMUM DIMENSIONS Length (Inches)	Width (Inches)	Depth (Inches)
203-1	3.125	1.00	3.125
-2	4.500	1.625	3.750
-3	3.125	1.00	3.125
-4	2.500	1.00	3.00
-5	3.750	1.380	3.500
-6	3.125	1.00	3.125

Part #	Category	Quantity	Port Size (Dash No.)	Sensor Flow (GPM)			Δ p at Max. Flow & 100°F	Maximum Weight Lbs.
				Normal	Trip	Maximum		
203-1	B	1	-8	4.00	9.5±1.5	42	160	0.57
-2	A*	1	-16	6.75	12±1	84	40	1.39
-3	A	1	-8	0.17	0.5±.1	6.5	25	0.57
-4	B	2	-6	0.60	1.5±.25	14	60	0.45
-5	A	1	-12	1.50	4.5±1	28	25	1.07
-6	A	1	-8	0.26	0.75±.125	3.5	15	0.57

*Category A units have shunt lockouts incorporated

TABLE II

SPECIFICATION 203 REVISION SHEET

DATE	DESCRIPTION	REV. LETTER
13 Jan 78	Original Issue	
21 Feb 78	Page (1) - Added Revision Letter and Date Page (2) - Added Weight Paragraph Page (3) - Added Envelope Values Page (4) - On - 1 9.5±1.5 was 9±1; 160 psid was 15; 0.52 lbs. was 0.50 lbs. On - 2 Added asterisk & defined category A units. On - 3 0.52 lbs. was 0.40 On - 4 1.5±.25 was 1.5±0.1; 60 psid was 15 psid On - 5 1.02 lbs. was 0.70 lbs. On - 6 0.75±.125 was 0.100; 25 psid was 15 psid; 0.52 lbs. was 0.40 lbs.	A
09 March 78	Page (1) - Added indicator thermal lock out requirements. Page (4) - Table 2 On - 1 0.57 lbs. was 0.52 lbs. On - 2 1.39 lbs. was 1.34 lbs. On - 3 0.57 lbs. was 0.52 lbs. On - 5 1.07 lbs. was 1.02 lbs. On - 6 0.57 lbs. was 0.52 lbs.; 15 psid was 25 psid	B

Specification 204
01 April 1978

Grumman Aerospace Corporation
Bethpage, New York 11714
HYCOS Φ II

Specification: Pressure Switch, Temperature Compensated

Purpose:

The temperature compensated pressure switch is a device which provides a visual and electrical signal to indicate a low pneumatic pressure condition.

The switch has a floating trip point that follows the normal gas laws during temperature compensation. This allows detection of low pneumatic pressure irrespective of gas temperature.

Design Requirements:

Each unit shall meet all the design requirements listed below.

Size: The pressure switch shall not exceed the envelope shown in Figure 1 . Means of effectively reducing size without imparing performance or reliability would be preferred.

Weight: The dry weight of the unit shall not exceed 0.3 lbs. Weight reduction is an important consideration factor.

Pressures:

Operating	3000 psi
Proof	5000 psi
Burst	7500 psi

Temperature:

Ambient	-65 to 300°F
Gas	-65 to 275°F

Leakage:

Internal	0.1 Std. CC
External	1 SCC/HR Maximum
	at 3000 psi over entire operating temperature range

Fail Safe:

The unit shall be so designed that in the unlikely event of an internal switch failure, the integrity of the system will not be compromised.

Switch Operation:

For the -1 assembly: On decreasing pressure and at any gas temperature between -65 and 275°F, the pressure switch shall actuate between bands "B" and "C" as shown in Figure 2.

On increasing pressure and at any gas temperature between -65 and 275°F, the switch shall operate between bands "A" and "B" after the visual indicator is manually reset.

For the -2 assembly: On decreasing pressure and at any gas temperature range between -65 and 275°F, the pressure switch shall actuate between bands "B" and "C" as shown in Figure 3.

On increasing pressure and at any gas temperature between -65 and 275°F, the switch shall operate between bands "A" and "B" after the visual indicator is manually reset.

Both the -1 and -2 assemblies shall employ a single pole double throw switch of military grade quality.

Switch Indication and Reset:

Switch indication shall be both visual and electrical at the required operating parameters. The electrical schematic shall be in accordance with Figure 1.

Switch reset shall occur only when the visual indicator is manually reset.

Service Life:

Each switch model shall be capable of at least 100,000 pressure/temperature cycles without degradation of performance.

Component Quality:

Each switch detail shall be constructed of best available military quality hardware/processed for maximum reliability suitable for limited flight testing.

Fluid:

The operating fluid shall be dry nitrogen or compressed air with a dew point of -65°F or lower.

SPECIFICATION 204

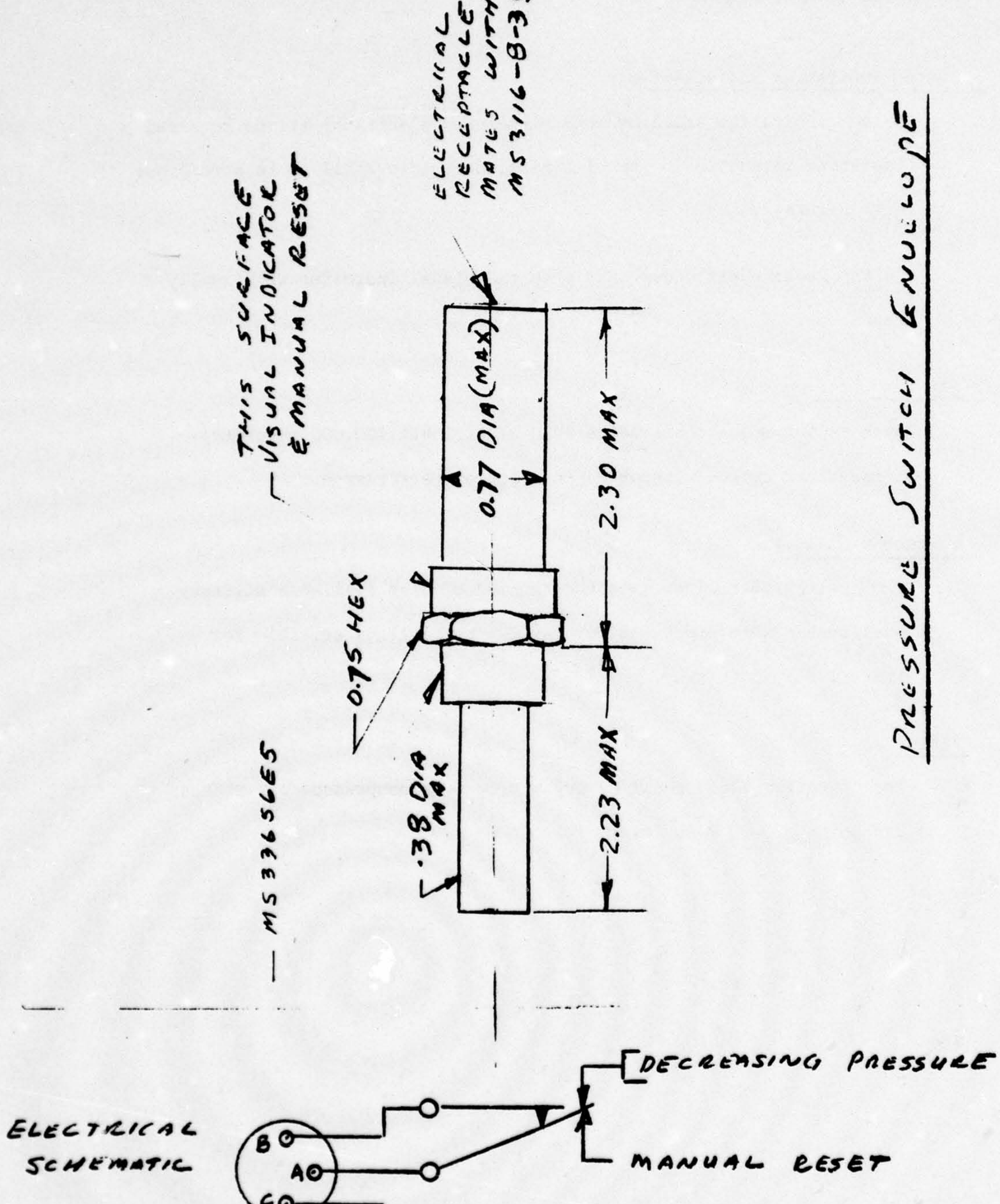
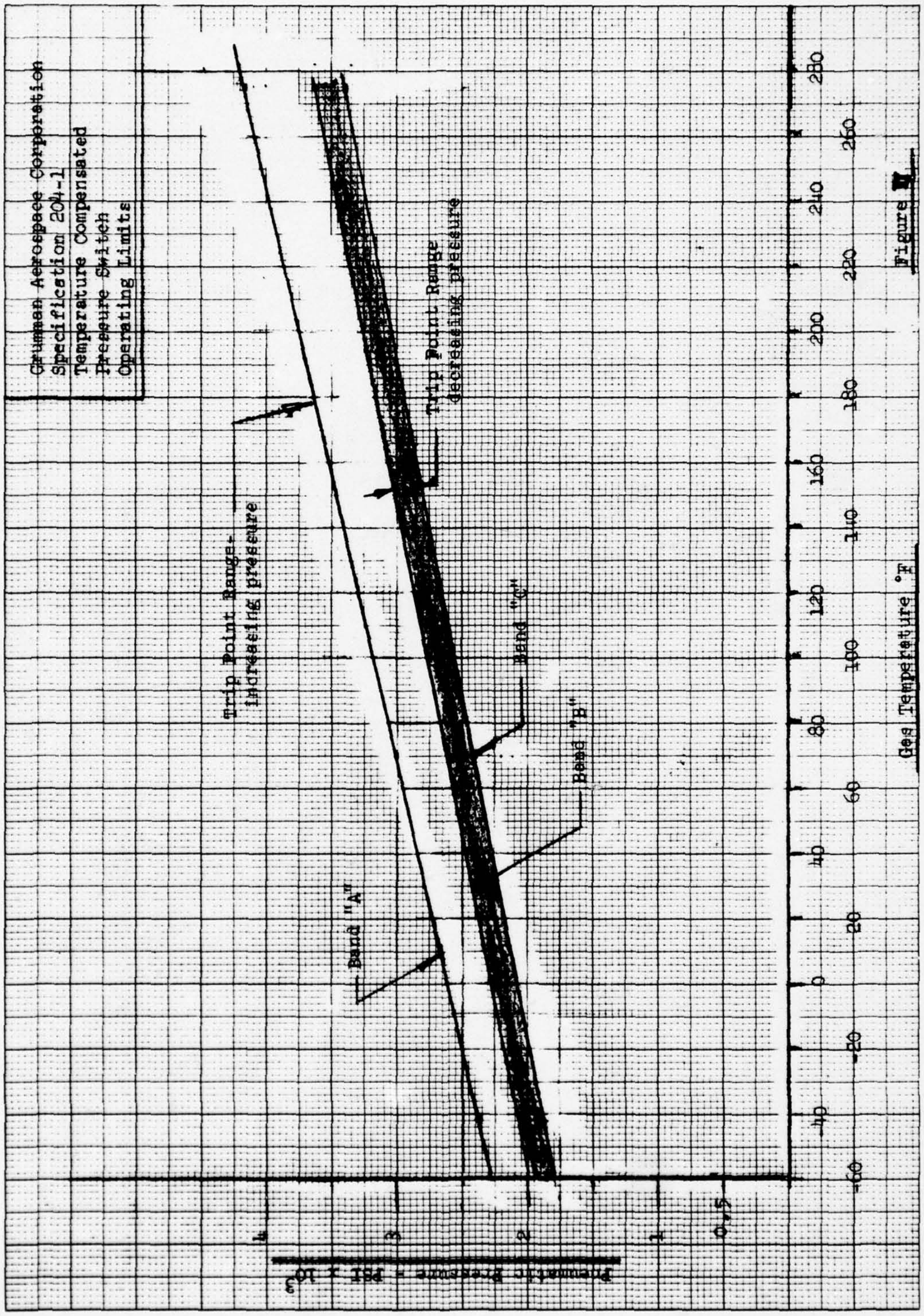
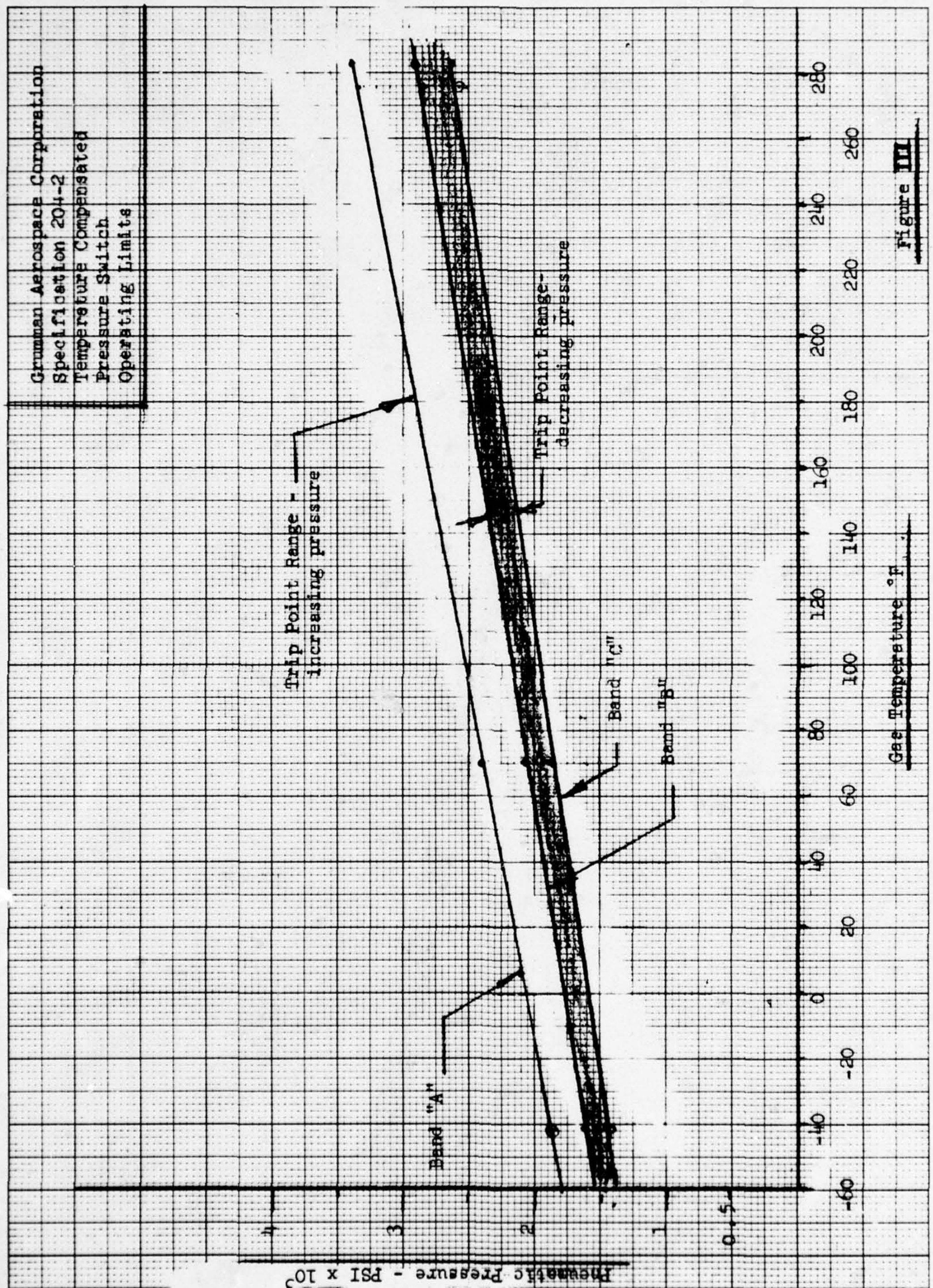


FIGURE I

16


Grumman Aerospace Corporation
Specification 204-1
Temperature Compensated
Pressure Switch
Operating Limits
Trip Point Range-
increasing pressure
Trip Point Range
decreasing pressure
Band "A"
Band "B"
Band "C"
Pneumatic Pressure - PSI x 10³
4
3
2
1
0.5
Gas Temperature °F
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
Figure



Grumman Aerospace Corporation
Specification 204-2
Temperature Compensated
Pressure Switch
Operating Limits
Trip Point Range -
increasing pressure
Trip Point Range-
decreasing pressure
Band "A"
Band "C"
Band "B"
Pneumatic Pressure - PSI x 10^3
4
3
2
1
0.5
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
Gas Temperature °F
Figure III

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Specification Number 205
14 April 1978

GRUMMAN AEROSPACE CORPORATION

BETHPAGE N.Y. 11714

SPECIFICATION: Moisture Indicator, Visual Type

PURPOSE: The moisture indicator shall be used as an in line indicator for remote monitoring of a low pressure pneumatic system.

REQUIREMENTS: Each unit shall meet the following requirements:

Size - 5.06" x 1.59" x 3.18" maximum

Operating Pressure 100 psi maximum

Ports: AND 10050-4

Weight: 0.34 pounds maximum

Desiccant: MIL-D-3716 Type A Grade H

Absorption Capacity: .02 lbs. water minimum

Temperature Range - 65 to 160^{o}F.

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Specification 206C
23 June 1978

GRUMMAN AEROSPACE CORPORATION

BETHPAGE NEW YORK 11714

HYCOS O II

Specification: Cable, Fiber Optic

Purpose: The fiber optic cable will be used to transport white light and colors from a surface to a remote point with minimum cable and interface loss. It will be used in an aircraft vehicle environment subject to those conditions encountered during military operations.

Design Requirements

1. Description - The fiber optic cable will connect point "A" interface to point "B" interface with minimum transmission and coupling loss. Connectors as defined below will be supplied with each length.

2. Operating Environment

(a) Ambient - 65 to 275°F.
(b) Cable surface and connectors shall be impervious to hydraulic oil (MIL-H-5606); jet fuel JP5; and most cleaning solvents.
(c) The cable shall be capable of being supported using standard MS type clamps without causing fiber breakage.

3. Physical Property Requirements

A. For lengths of up to 25 feet the radiation transfer index shall not be less than 0.6.

B. Number of fibers	222-234
Fiber diameter	.0031"
Bundle diameter	.045"
Numerical aperture	0.56
Acceptance cone angle	68°
Core Index of refraction	1.62
Optical attenuation	db/meter
Maximum fiber breakage	10% at 30 meters
Tensile strength	40 lbs. minimum with strength members
C. Jacket material	Tefzel 200 undercoating, Hytrel overcoating
Outside diameter	.160
Wall thickness	.020
Minimum bend radius	0.43"

3. Physical Property Requirements (Continued)

D. Connectors: Connectors in accordance with proposed MIL-C-85044/1 shall be used for both ends. (Reference I attachment)

E. Cable length measured from the polished faces shall be:

Dash Number	Length
-1	8'
-2	10'
-3	12'
-4	15'
-5	25'
-6	10"
-7	8' *
-11	4.75**
-13	4.75**
-14	10.62**
-15	10.62**

* SEE FIGURE 9

** SEE FIGURE 10

MILITARY SPECIFICATION SHEET

CONNECTOR, FIBER OPTIC, PRESSURIZED BULKHEAD, TYPE I, CLASS 1

This specification is approved for use by all departments and agencies of the Department of Defense.

The complete requirements for procuring the fiber optic connector described herein shall consist of this document and the issue in effect of MIL-C-85044.

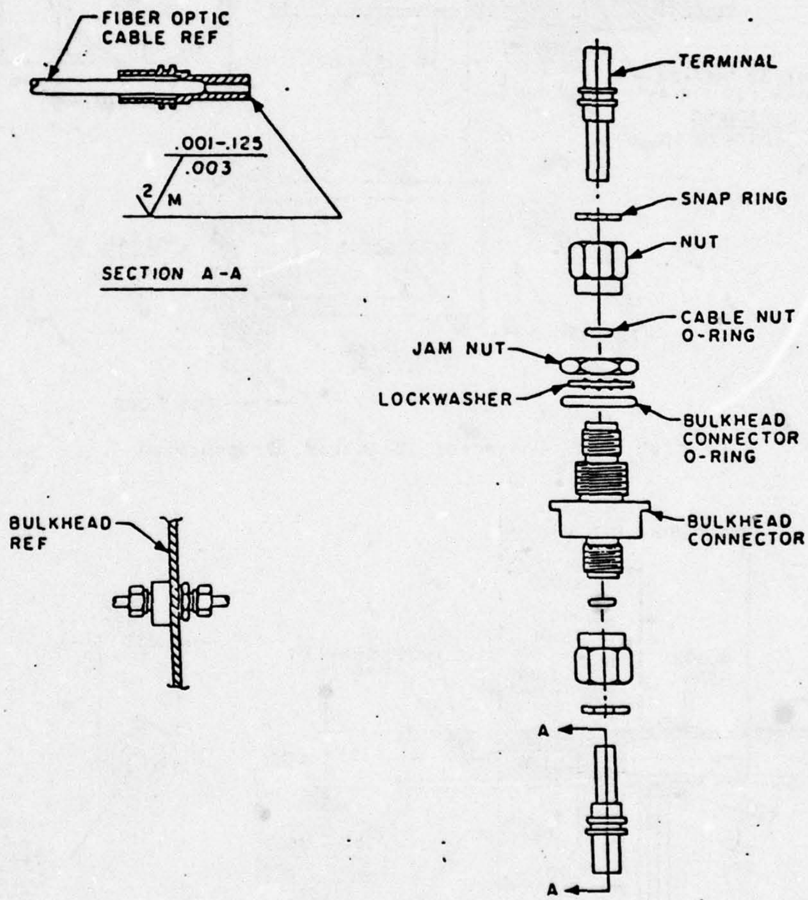


Figure 1.

REFERENCE I

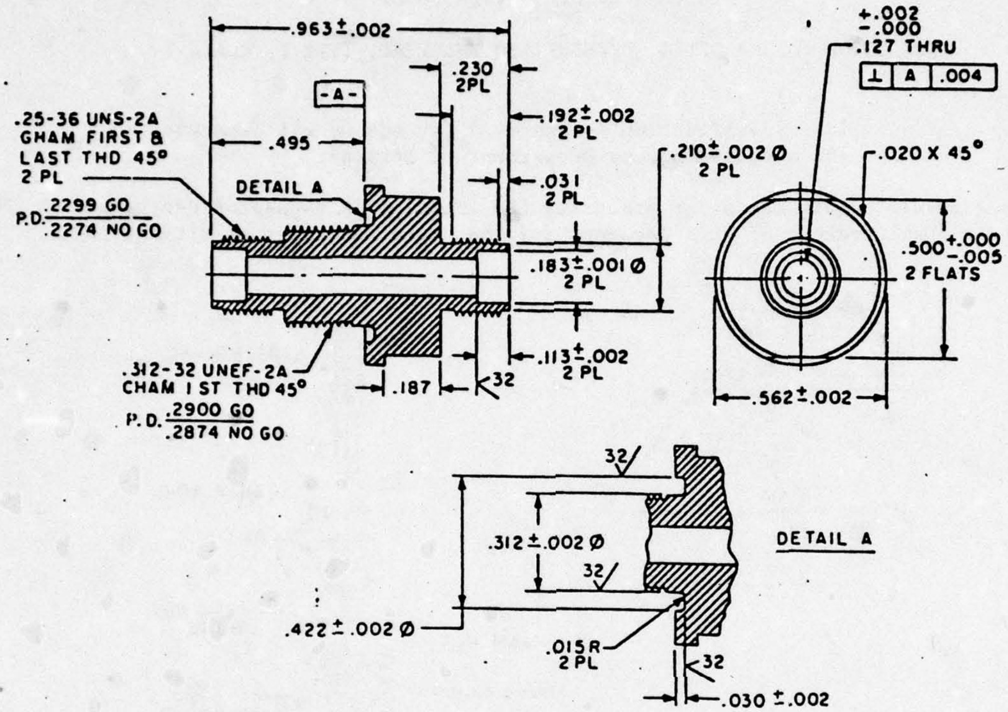


Figure 2. Connector, Bulkhead, Pressurized

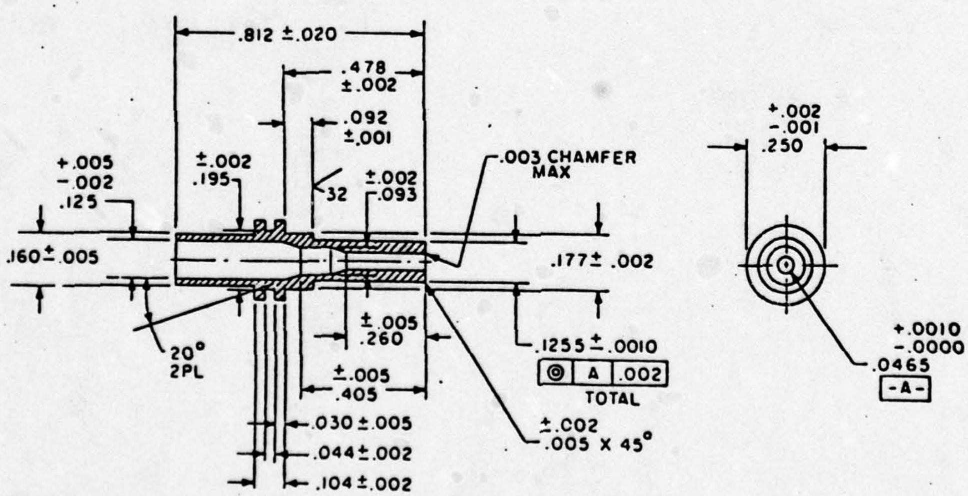


Figure 3. Terminal, Cable, Fiber Optic

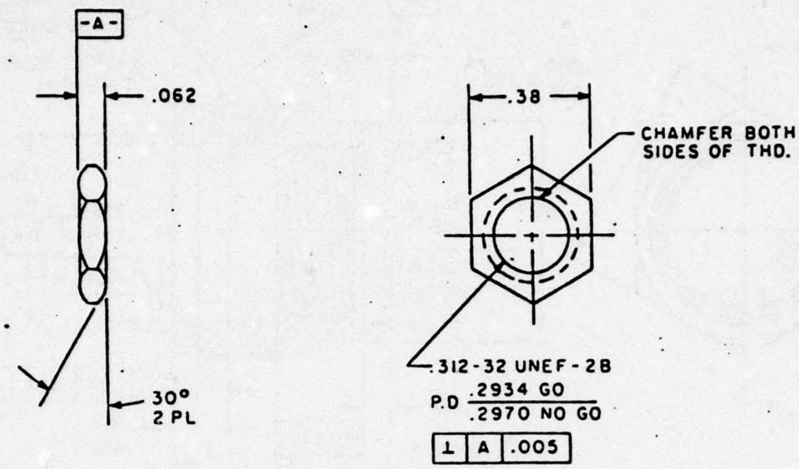


Figure 4. Nut, Jam, Connector

	A	B	C
CABLE NUT O-RINGS	.031	.125	.187
BULKHEAD CONNECTOR O-RING	.050	.312	.412

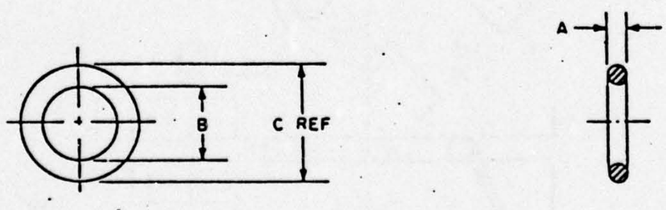


Figure 5. O-rings

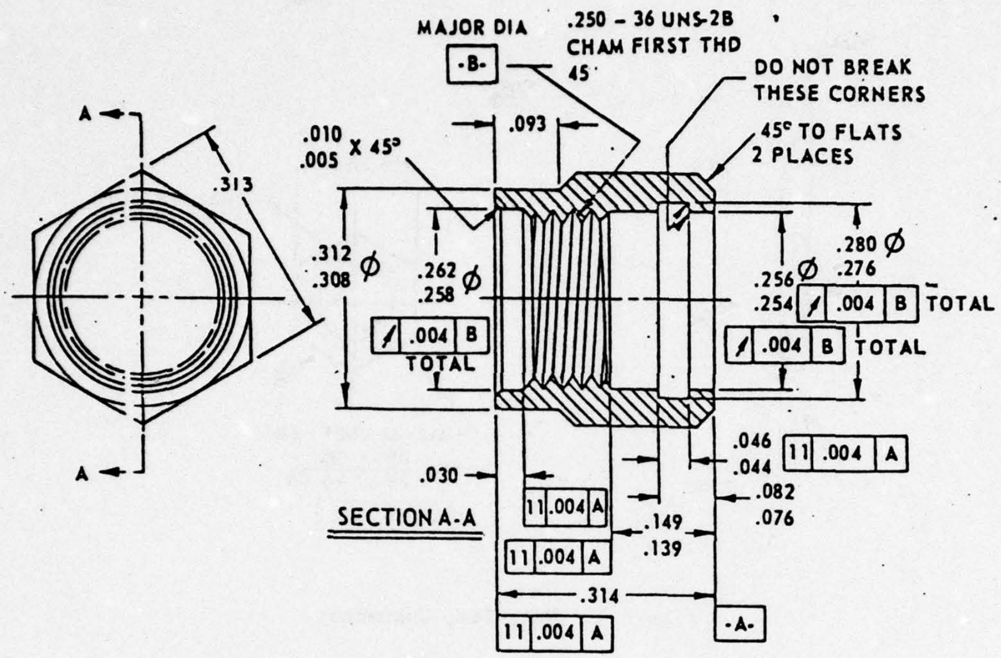


Figure 6. Nut, Coupling

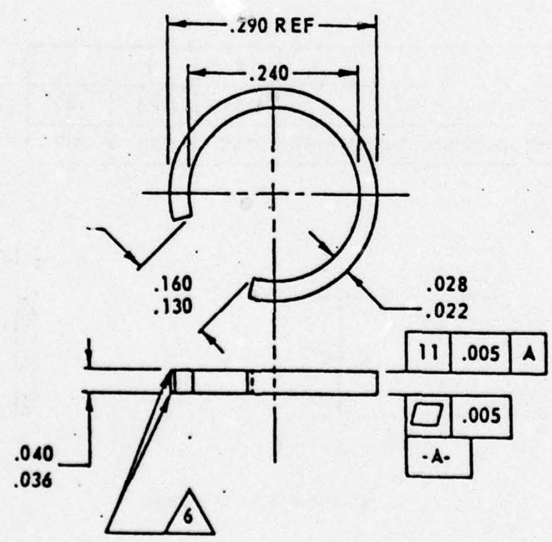


Figure 7. Ring, Snap

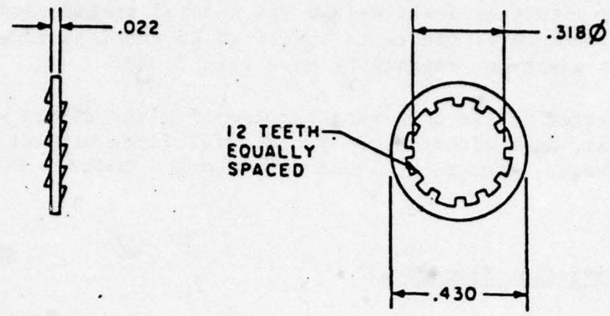


Figure 8. Washer, Lock, Internal Tooth

REQUIREMENTS:

1. Material. As specified in the general specification.

2. Terminal Barrel. The terminal barrel shall be rough-finished using a 1500 mesh diamond lap, or equivalent, so the fibers are not crushed.

3. Optical finishing. The final finish of the fiber optic terminal face shall be obtained using aluminum oxide polishing compound on a phenolic lap. The finish roughness shall be 2 microinches or less. The finish waviness shall be .001 inches or less over the entire terminal end, as defined in USAS B 46.1.

4. Connector Assembly. The terminals shall be tightened to between 3 and 7 inch-pounds torque.

5. Pressurization. The connector shall be pressurized initially to a gauge pressure of 30-pound force per square inch (lbf/in.^{2}) $\pm$ 5 lbf/in^2. The pressure shall not drop more than 5 lbf/in.^{2} during a 24-hour period at 25°C. The volume sealed by the connector shall be less than 1 cubic foot. The connector shall maintain the required gauge pressure of 30 lbf/in.^{2} after temperature stabilization during the equipment operating steps of the temperature/altitude test of MIL-T-5422 for class 2 operation and during shock and vibration tests.

6. Optical. The maximum acceptable relative optical connector loss shall be 3dB + 0.3dB for cable lengths of from 1 to 10 feet. Connector loss shall be measured using a test as described in the general specification. During and after the performance of the tests specified in the general specification, the connector loss shall not degrade by more than 0.5dB.

7. Jacketed cables employing bundles of glass fibers when secured to their terminals, must withstand 30 pound axial force without terminal separation or fiber breakage. Mechanical locks with strength members edixied to end tip.

NOTES:

1. Termination Procedure:

1.1 Roughen the surface of the jacket with sandpaper 1-1/2 inches from the end of the cable. Make sure that deep grooves are placed in the jacket. This assures a good epoxy bond.

1.2 Strip 1 inch of jacket off the cable using a #16 hole in standard wire strippers.

1.3 Dip the exposed glass fibers in alcohol to pull the fibers together. Wipe off excess. Do not get the jacket wet. There should be 1 inch exposed glass fibers on the end of the cable.

1.4 Carefully slip the terminal onto the glass fibers to the edge of the jacket. If the glass is hanging up within the terminal, the fibers will bow-out. Rotating the terminal should eliminate this problem. Heat the terminal and fibers with a heat gun to dry the alcohol.

1.5 Apply the epoxy to the roughened jacket. Slide the terminal over the jacket and wipe the excess epoxy off.

1.6 Cut the fibers, leaving 1/4 inch of exposed fibers extending beyond the terminal.

1.7 Apply epoxy to the exposed fibers. Work the epoxy into the fibers, to eliminate air bubbles.

1.8 Heat the exposed glass fibers with a heat gun to cure the epoxy. The epoxy will turn a dark red when cured. Gradually apply the heat down the length of the terminal. Be sure to cure the epoxy at the jacket-terminal interface. The cable should be held horizontal to prevent epoxy from dripping down the cable.

It is easier to see the epoxy turn red, if a small amount of epoxy is put on the terminal, right at the jacket-terminal junction. Care must be taken not to over-heat the jacket. The maximum jacket temperature should not be exceeded (150 C for Hytrel). A temperature check of the heat gun is recommended.

1.9 Grind the glass down to the stainless steel terminal face using a rotating lap system and a 1500 mesh diamond-bonded metal lap. The lap should be run wet.

1.10 Polish the glass and stainless steel on a phenolic lap, using aluminum oxide in solution.

1.11 Assemble the terminal, snap-ring, nut, and O-ring.

PART No. M85044/1-1

Review activity:

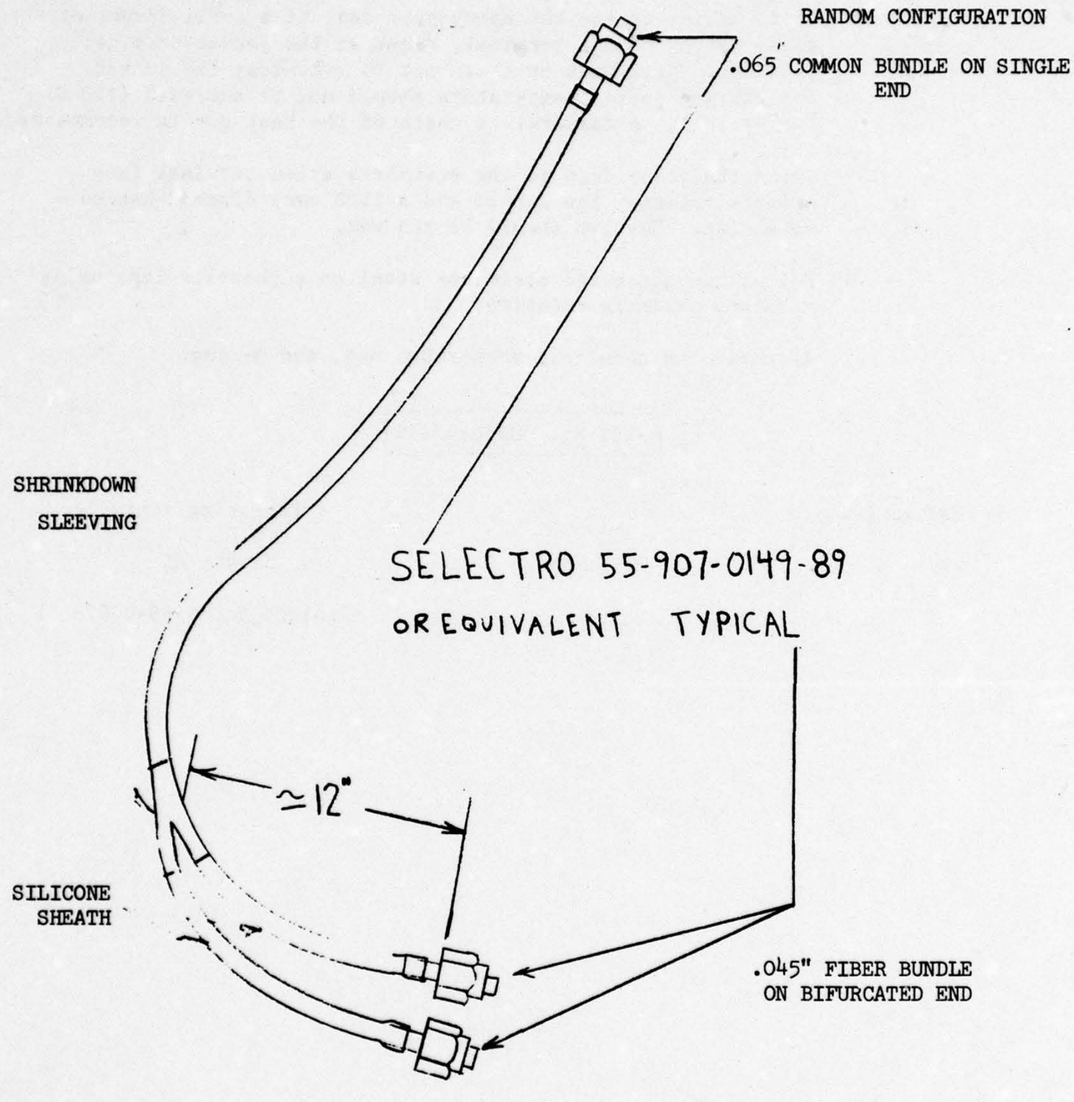
Navy - EC

Preparing activity:

Navy - AS

(Project No. 9999-0007- .)

GAC 206



LENGTH 8' -7 1 BIFURCATED END

FIGURE 9

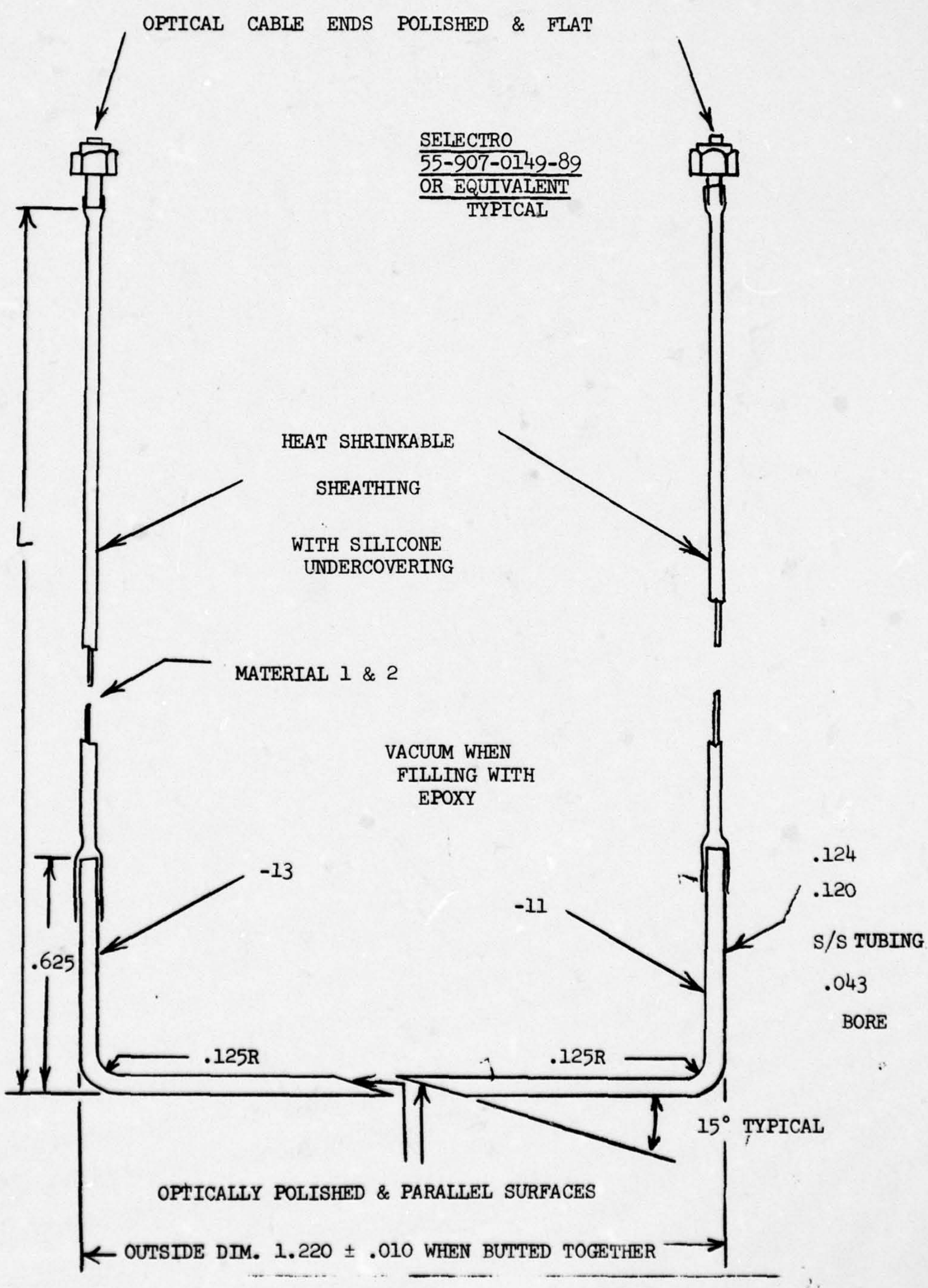

OPTICAL CABLE ENDS POLISHED & FLAT
SELECTRO
55-907-0149-89
OR EQUIVALENT
TYPICAL
HEAT SHRINKABLE
SHEATHING
WITH SILICONE
UNDERCOVERING
L
L_1=4.75"
L_2=10.62"
MATERIAL 1 & 2
VACUUM WHEN
FILLING WITH
EPOXY
-13
-11
.124
.120
S/S TUBING
.043
BORE
.625
.125R
.125R
15° TYPICAL
OPTICALLY POLISHED & PARALLEL SURFACES
OUTSIDE DIM. 1.220 ± .010 WHEN BUTTED TOGETHER

FIGURE 10

Specification Number 207
02 May 1978

GRUMMAN AEROSPACE CORPORATION

BETHPAGE N.Y. 11714

SPECIFICATION: Transformer, Linear Variable Differential

V O I D E D

31

Specification 208
05 April 1978

GRUMMAN AEROSPACE CORPORATION

BETHPAGE N.Y. 11714

SPECIFICATION: Liquid Sensor, Pneumatic

SEE GAC DRAWING NUMBER 1491901-307

Specification 209
01 March 1978

GRUMMAN AEROSPACE CORPORATION

BETHPAGE, NEW YORK 11714

HYCOS Ø II

SPECIFICATION: POTENTIOMETER, ROTARY

PURPOSE: The purpose of the rotary potentiometer is to measure angular displacement of a reservoir tape spool.

DESIGN REQUIREMENTS:

Potentiometer Type:	ten turn
Element:	wire wound
Mount Type:	bushing
Physical Dimensions:	
OD:	0.875
Pot Length:	1.00
Fitting and Shaft Length:	11/16
Shaft Diameter:	0.2497
Length:	0.50
Thread Interface:	3/8-32 UNEF 2A
Electrical Specifications:	
Resistance:	20,000 Ohms
Linearity:	0.20
Power Rating:	2 watts
Operating Temperature Range:	65°F to 255°F
Torque:	0.60 oz.in. maximum
Weight:	1.0 oz. maximum

Specification 210
29 March 1978

GRUMMAN AEROSPACE CORPORATION

BETHPAGE, NEW YORK 11714

HYCOS ϕ II

Specification: Temperature Probe, Analog Output

Purpose: The temperature probe is a device which provides a linear analog signal in direct proportion to the temperature it senses for use in a hydraulic monitoring system.

Design Requirements

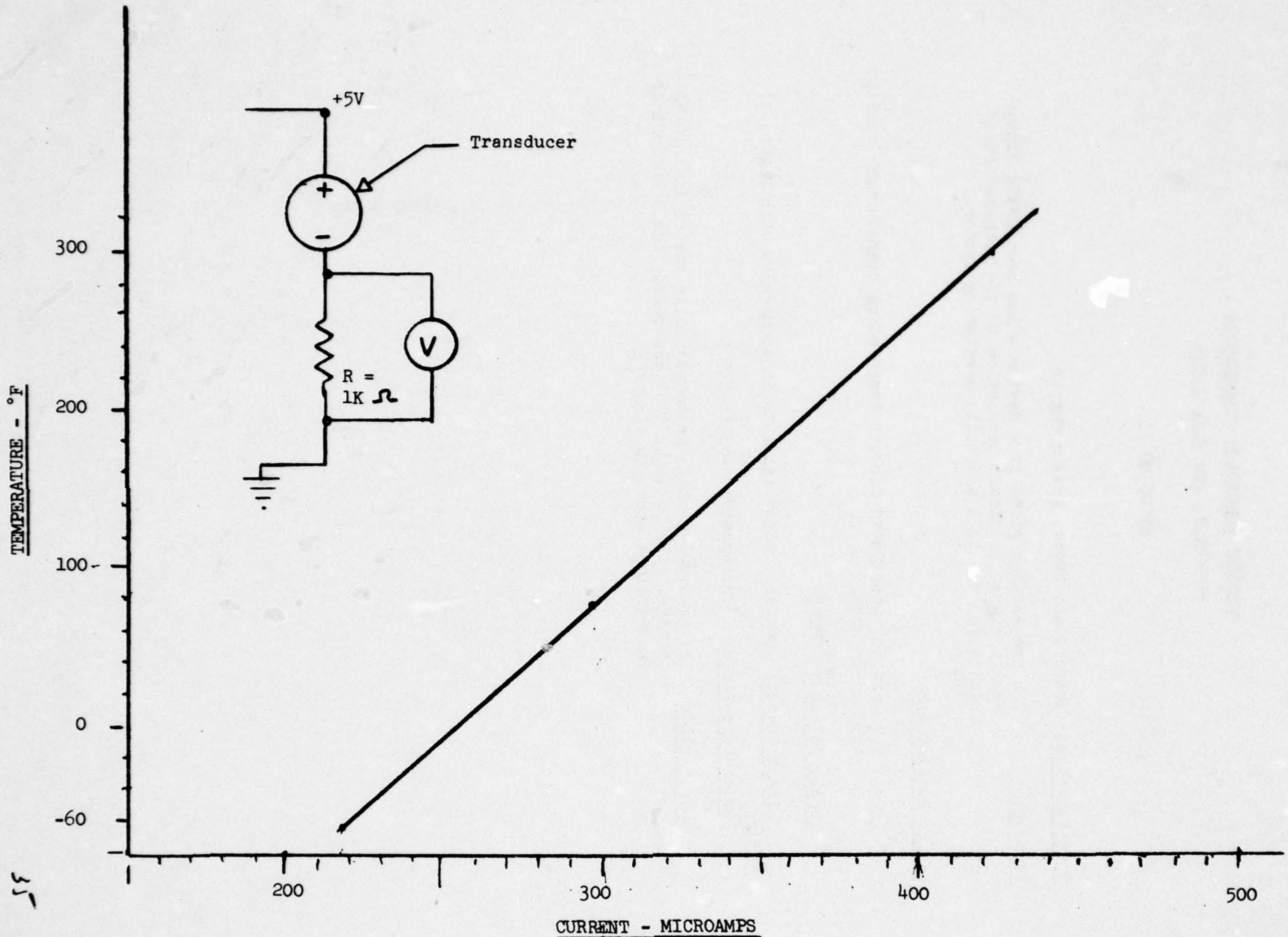
Type: Two terminal integrated circuit temperature transducers (voltage in/Current out).

Supply Voltage: 5 VDC

Current Output: Current output shall be in accordance with Figure I.

Temperature Range: Performance: -65 to 275°F.

Construction: The transducer shall be hermetically sealed in a TO-52 package. The package, then assembled, shall conform to the envelope shown in Figure II.

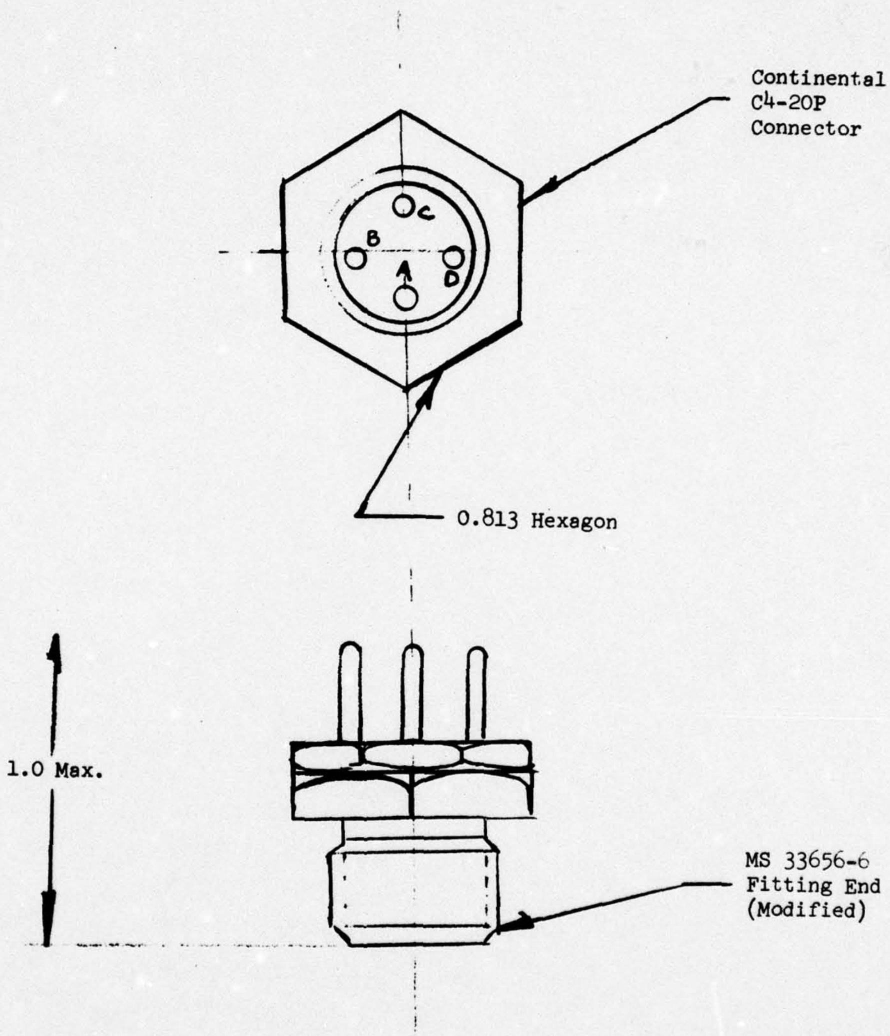


+5V
Transducer
R =
1K Ω
V
TEMPERATURE - °F
300
200
100
0
-60
200
300
400
500
CURRENT - MICROAMPS

FIGURE I

35

Part Number 203-1



TEMPERATURE PROBE ENVELOPE

FIGURE II

36

Specification 211
13 May 1978

GRUMMAN AEROSPACE CORPORATION

BETHPAGE N.Y. 11714

Specification: Transducer, miniature, pressure

Purpose: The pressure transducer will be used to measure pressure variations in pneumatic and hydraulic systems.

Design Requirements

1. Description-the Pressure Transducer is a thread mounted pressure sensor. It measures static and dynamic pressures, in full scale ranges from 8 to 3000 psi. The transducer shall be a semiconductor strain gauge device, made from stainless steel in a 10-32 UHF threaded housing with an O-ring seal. The standard transducer shall have at least 2 ft. of teflon insulated cable with a compensation module located 18" from the sensor.

Full scale output shall be 125 MV for a 6VDC excitation. It shall have a combined nonlinearity and hysteresis to ±.59. full scale. THE EPS 1032 is useful in a range of 20% of its resonant frequency.

2. Operating Environment

Altitude-0-50,000 ft.
Vibration environment -±10g, 0 to 2,000 Hz
Shock-±10g in 3 mutually perpendicular planes
Pressure-3000psi nominal.

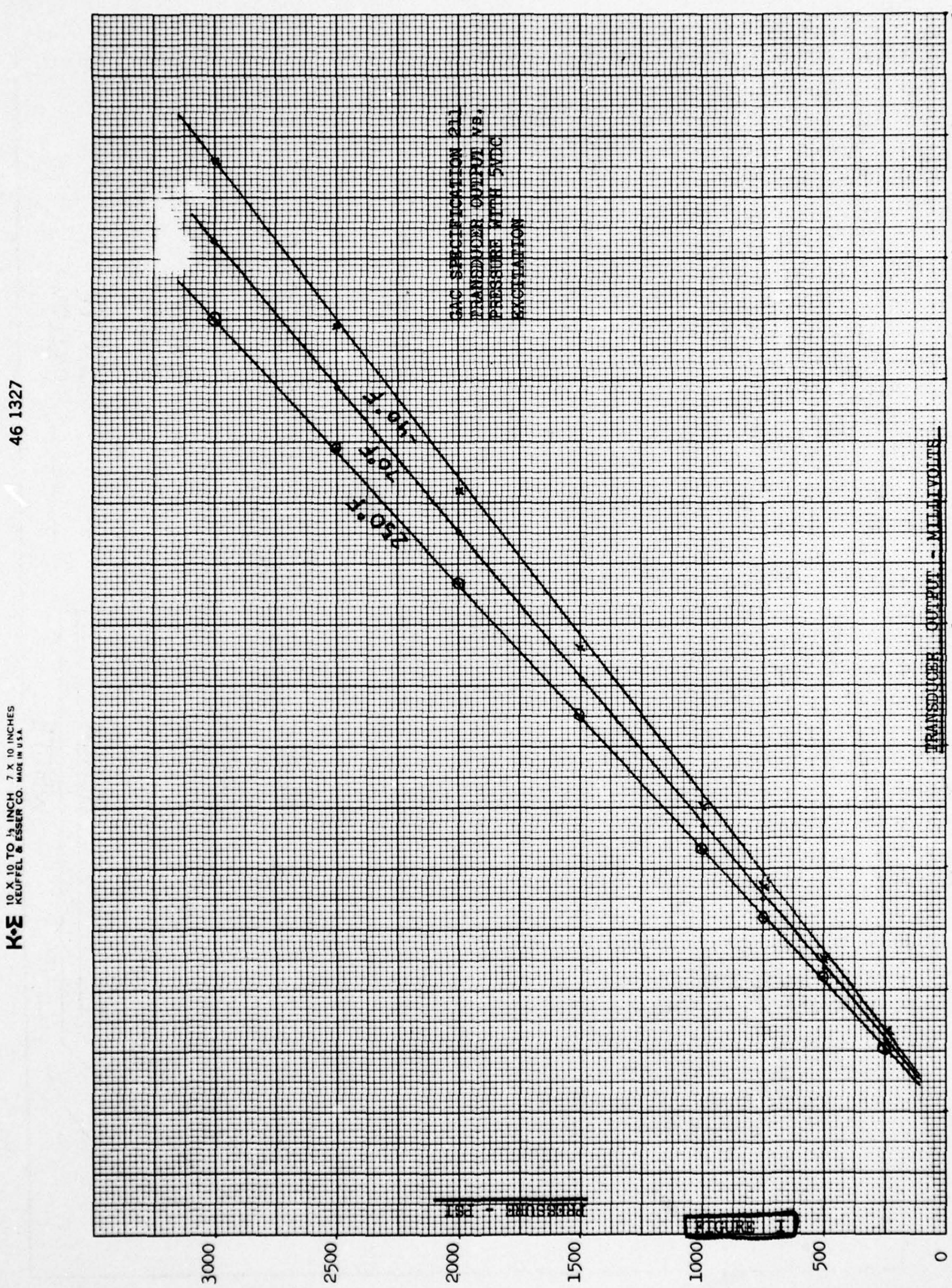
3. Physical Property Requirements

Range 2500 psi
Over-range-4000 psi
Sensitivity-.05 mv/psi (nom) at 6VDC
Excitation-5.0 VDC
Repeatability-.25%
Compensated Temperature Range- -65°F to 250°F

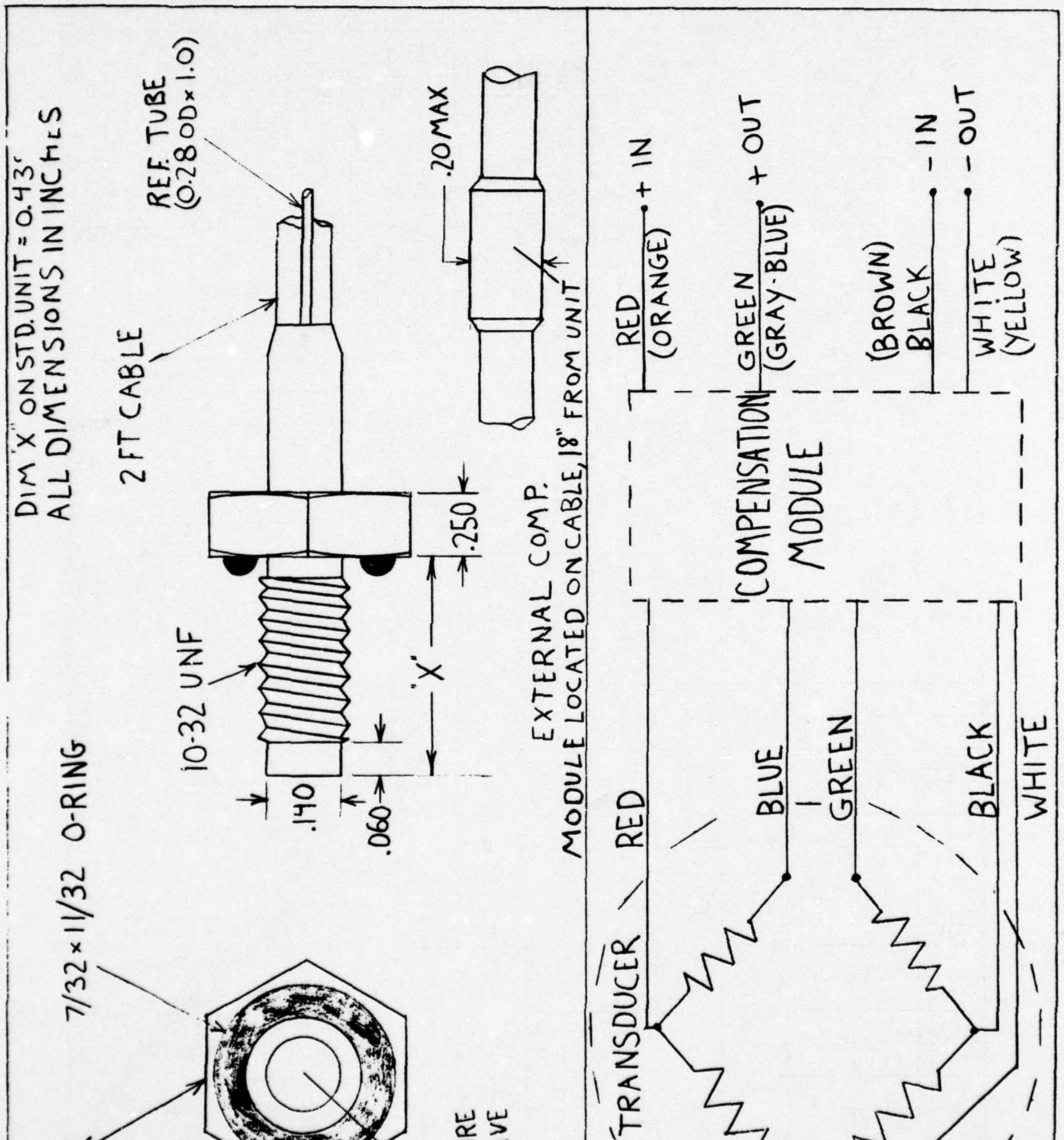
Op. Temperature Range -65°F to 275°F.

Performance shall be in accordance with figure (1)

The unit shall conform to Figure (2)



K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.
46 1327
GAC SPECIFICATION 211
TRANSDUCER OUTPUT VS.
PRESSURE WITH 5VDC
EXCITATION
-40°F
70°F
250°F
TRANSDUCER OUTPUT - MILLIVOLTS
PRESSURE - PSI
FIGURE 1
0
20
40
60
80
100
120
140
160
180
0
500
1000
1500
2000
2500
3000


3/8" HEX
7/32 × 11/32 O-RING
PRESSURE SENSITIVE AREA
10-32 UNF
.140
.060
"X"
.250
2 FT CABLE
REF. TUBE (0.28 OD × 1.0)
.20 MAX
DIM "X" ON STD. UNIT = 0.435
ALL DIMENSIONS IN INCHES
EXTERNAL COMP.
MODULE LOCATED ON CABLE, 18" FROM UNIT
TRANSDUCER
RED
BLUE
GREEN
BLACK
WHITE
COMPENSATION MODULE
RED (ORANGE)
+ IN
GREEN (GRAY-BLUE)
+ OUT
(BROWN) BLACK
- IN
WHITE (YELLOW)
- OUT

Specification 212
05 April 1978

GRUMMAN AEROSPACE CORPORATION

BETHPAGE N.Y. 11714

SPECIFICATION: Photo Diode, Large Area Silicon.

PURPOSE: The photo diode will be used in conjunction with the Glallium Arsenide Light Emitting Diode.

DESIGN REQUIREMENTS:

Active Area: 0.027 square inches

Shunt Resistance: R_S = 2 MEG OHM min.

Operating Temperature Range: -55°C to 125°C.

Peak Sensivity : 0.9 to 1.0 microns

Size: TO5

Physical Dimensions shall be in accordance with Figure 1.

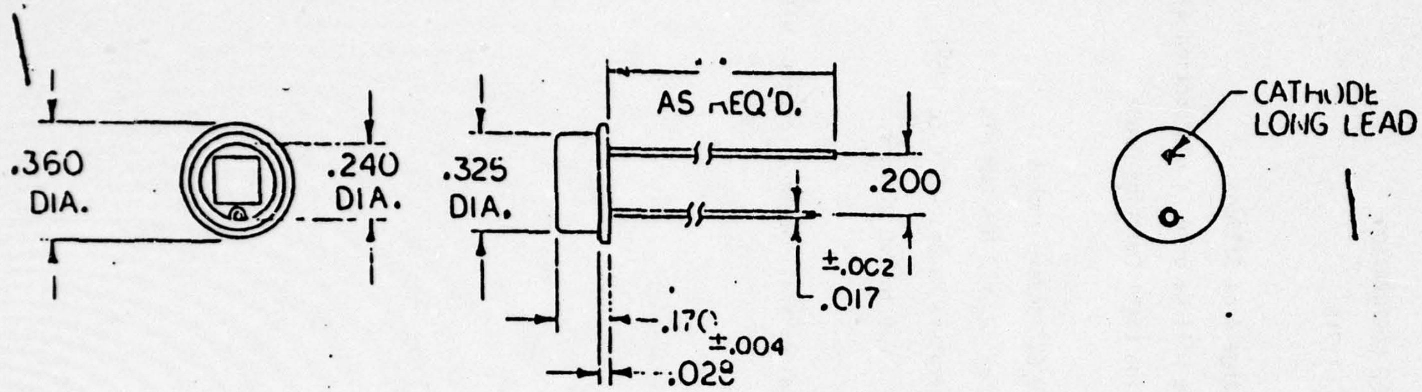


FIGURE I

PHOTO DIODE, LARGE AREA

Specification 213
05 April 1978

GRUMMAN AEROSPACE CORPORATION

BETHPAGE N.Y. 11714

SPECIFICATION: Diode, GaAr L.E.D.

PURPOSE: The Glallium Arsenide light emitting diode is used for generating a selected light source in a measurement system.

DESIGN REQUIREMENTS:

DESCRIPTION: The Glallium Arsenide infrared emitting diode shall be lensed in a hermetically sealed TO-46 package. It shall emit an intense band of radiation when forward biased.

PHYSICAL DIMENSIONS:

The physical dimension of the diode shall conform to figure 1.

OPERATING DATA:

Forward Current 100 Ma

Reverse Voltage 3.0 V

Storage Temperature 100^{o}C.

Operating Temperature -55 to 100^{o}C.

At 25^{o}C. electrical and optical characteristics shall be:

	Min	Typ	Max
Forward Voltage (I_f = 60 ma)			1.8
Reverse Voltage (I_r = 10 ua)	3.0		
Infrared Power Output (I_f = 50 ma)	3.0mw	5mw	
Peak Emission Wavelength		9300A	

Spectral output shall be as shown in figure 2.

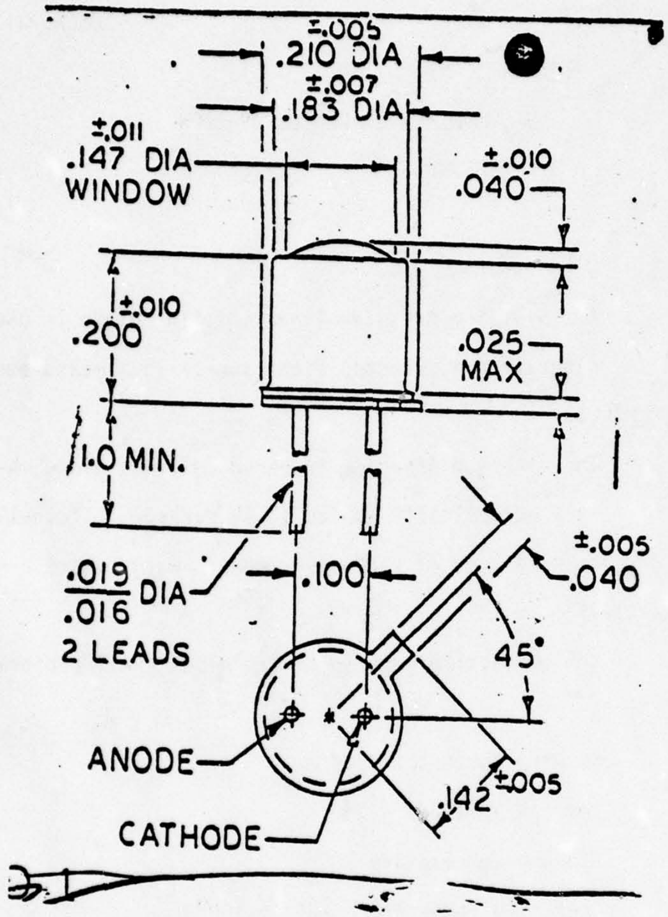
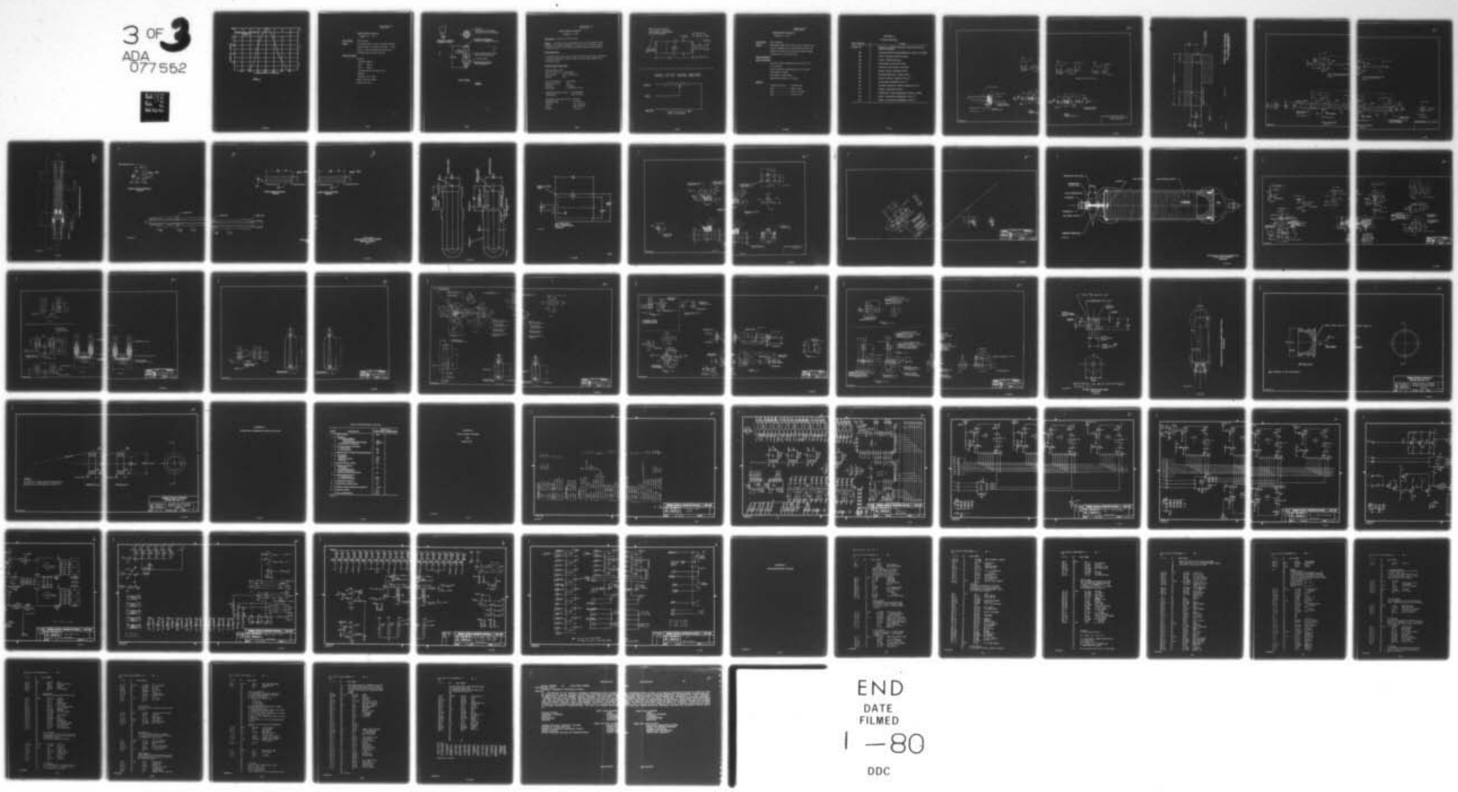

±.005
.210 DIA
±.007
.183 DIA
±.011
.147 DIA
WINDOW
±.010
.040
±.010
.200
.025
MAX
1.0 MIN.
.019
.016
DIA
2 LEADS
.100
±.005
.040
45°
ANODE
CATHODE
.142
±.005

FIGURE 1

AD-A077 552 GRUMMAN AEROSPACE CORP BETHPAGE NY F/G 13/7
HYDRAULIC DIAGNOSTIC MONITORING SYSTEM.(U)
MAY 79 J J DUZICH N62269-78-C-0041
UNCLASSIFIED NADC-TR-76389-30 NL

3 OF 3
ADA
077552



END
DATE
FILMED
1 -80
DDC

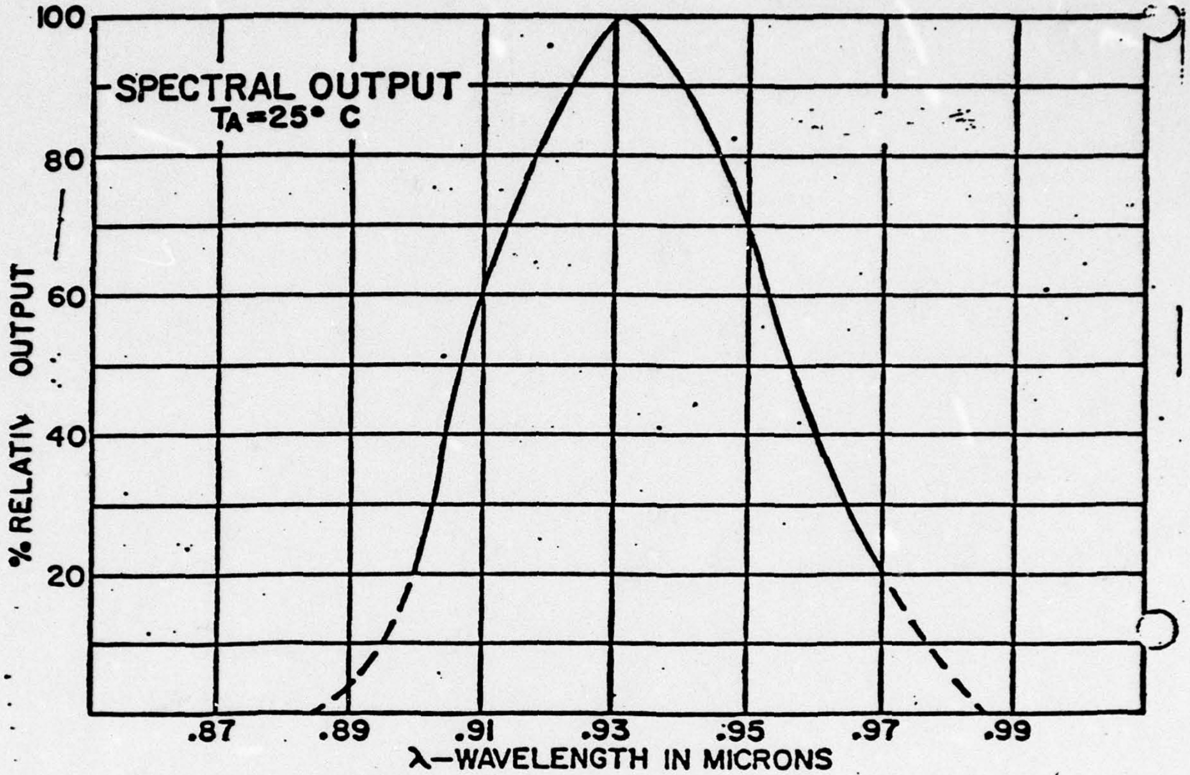

SPECTRAL OUTPUT
TA=25° C
100
80
60
40
20
% RELATIVE OUTPUT
.87
.89
.91
.93
.95
.97
.99
λ-WAVELENGTH IN MICRONS

FIGURE 2

Specification 214
16 June 1978

GRUMMAN AEROSPACE CORPORATION

BETHPAGE N.Y. 11714

SPECIFICATION: Switch Pressure

PURPOSE: The pressure switch is used in an airborne hydraulic system to detect a low pressure condition. It shall contain a single pole double throw switch with a threaded MS type electrical interface.

DESIGN REQUIREMENTS:

Pressures:

Operating: 3000 psi

Proof 4500 psi

Burst 7500 psi

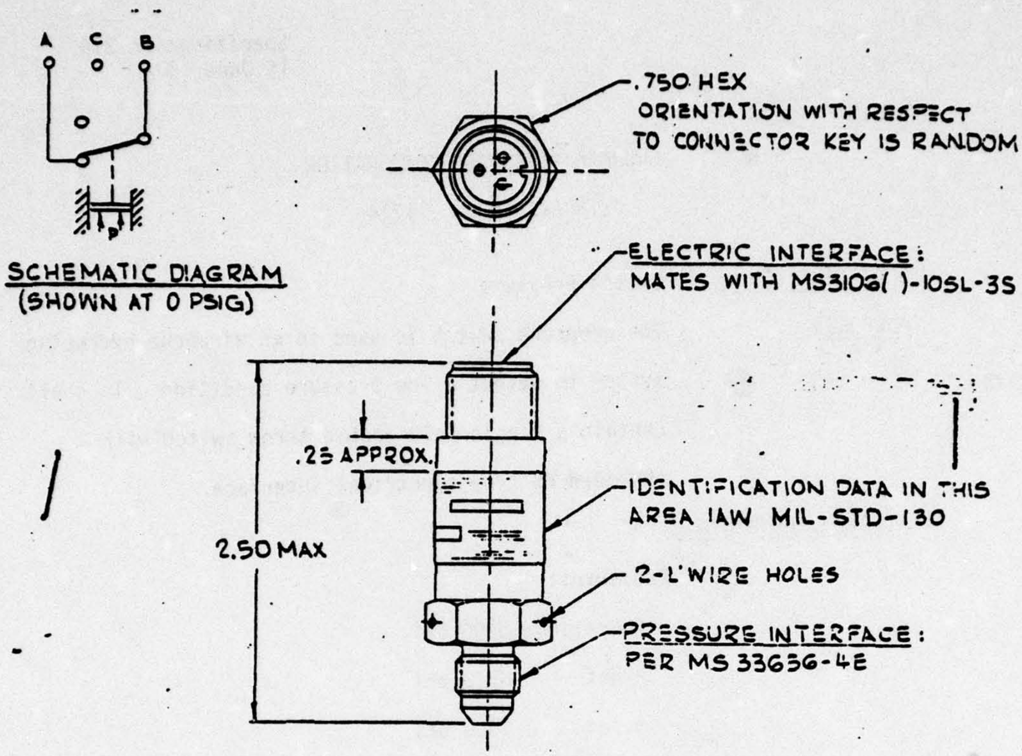
Actuation (decreasing) 2300 $\pm$ 100 psi

Temperature

Operating: -65 to 260^{o}F.

Weight: 0.085 lbs. Maximum

Envelope per Figure I



SWITCH, PRESSURE

FIGURE I

47

Specification 215
19 June 1978

GRUMMAN AEROSPACE CORPORATION

BETHPAGE N.Y. 11714

Specification : Transducer, Position, Linear

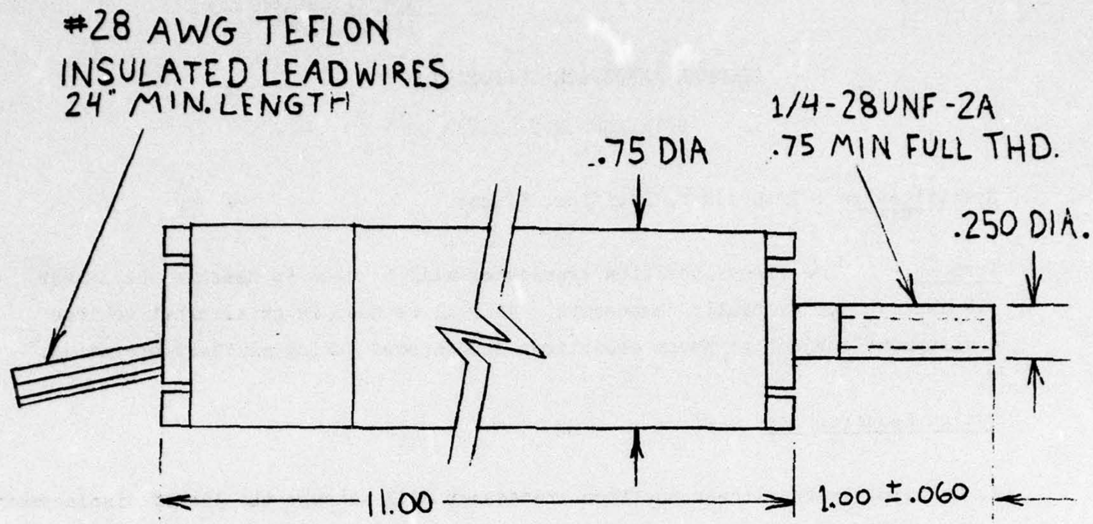
Purpose: The linear position transducer will be used to measure the linear displacement of hydraulic components. It will be used in an aircraft vehicle environment subject to those conditions encountered during military operation.

Design Requirements

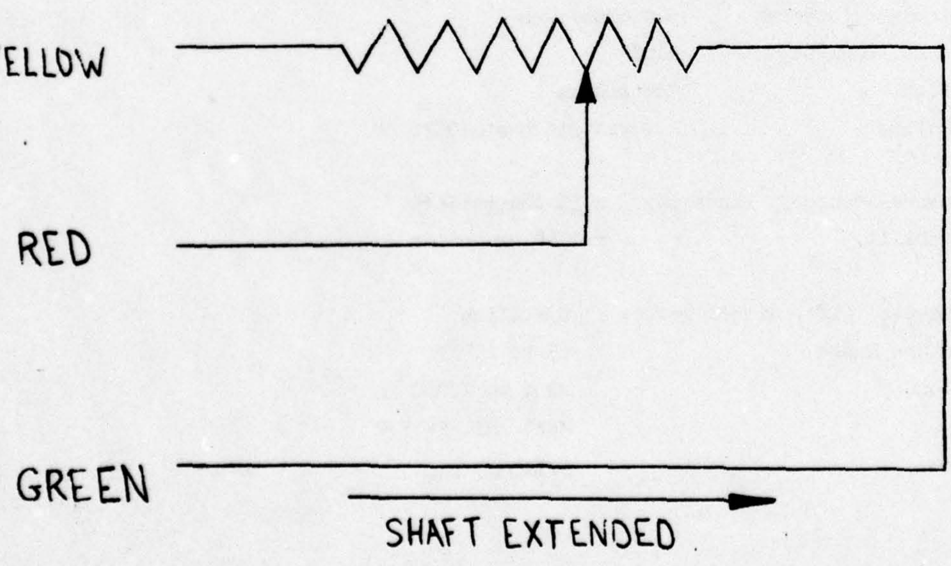
1. Description-The linear position transducer will measure the linear displacement of hydraulic components by having an output resistance change proportional to displacement change.

Physical Property Requirements

Mechanical-Range	8.00"
Shaft Actuation Force	1 pound maximum
Shaft rotation	360°-no discontinuity
Backlash	None
Electrical-Resistance	500 ohms/inch
Resistance tolerance	±10%
Resolution	Continuous
Power Rating	1.0 watt/inch at 70°F.
Performance-Accuracy, Linearity	±.5% independent
Repeatability	±.001" or better
Environmental Life, dither cycles	40 Million
Temperature Range	-65 to 250°F.
Vibration	20 G to 2,000 Hz
Others	Meet MIL-E-5572
Altitude	0-50,000 ft.



SINGLE OUTPUT WIRING DIAGRAM



Specification 216
13 April 1978

GRUMMAN AEROSPACE CORPORATION

BETHPAGE N.Y. 11714

SPECIFICATION: Motor, Mechanical

PURPOSE: The mechanical motor will be used to drive a constant force electrical component over a limited operating range. One element of the motor will be affixed to a movable element and the body will be ridigly affixed.

DESIGN REQUIREMENTS:

PHYSICAL DIMENSIONS:

The overall physical dimensions shall be 3-3/4 x 2-1/2 x 1-3/16 inches

Spring torque shall be approximately 1.56 inch pounds.

Cable tension 2.0 pounds

Cable length = 2 feet minimum

Output Spool Revolutions = 10 minimum

MATERIALS:

Constant Force Spring ..... Stainless Steel

Drums ....Nylon or Delrin

Base...................... Steel, Zinc plated

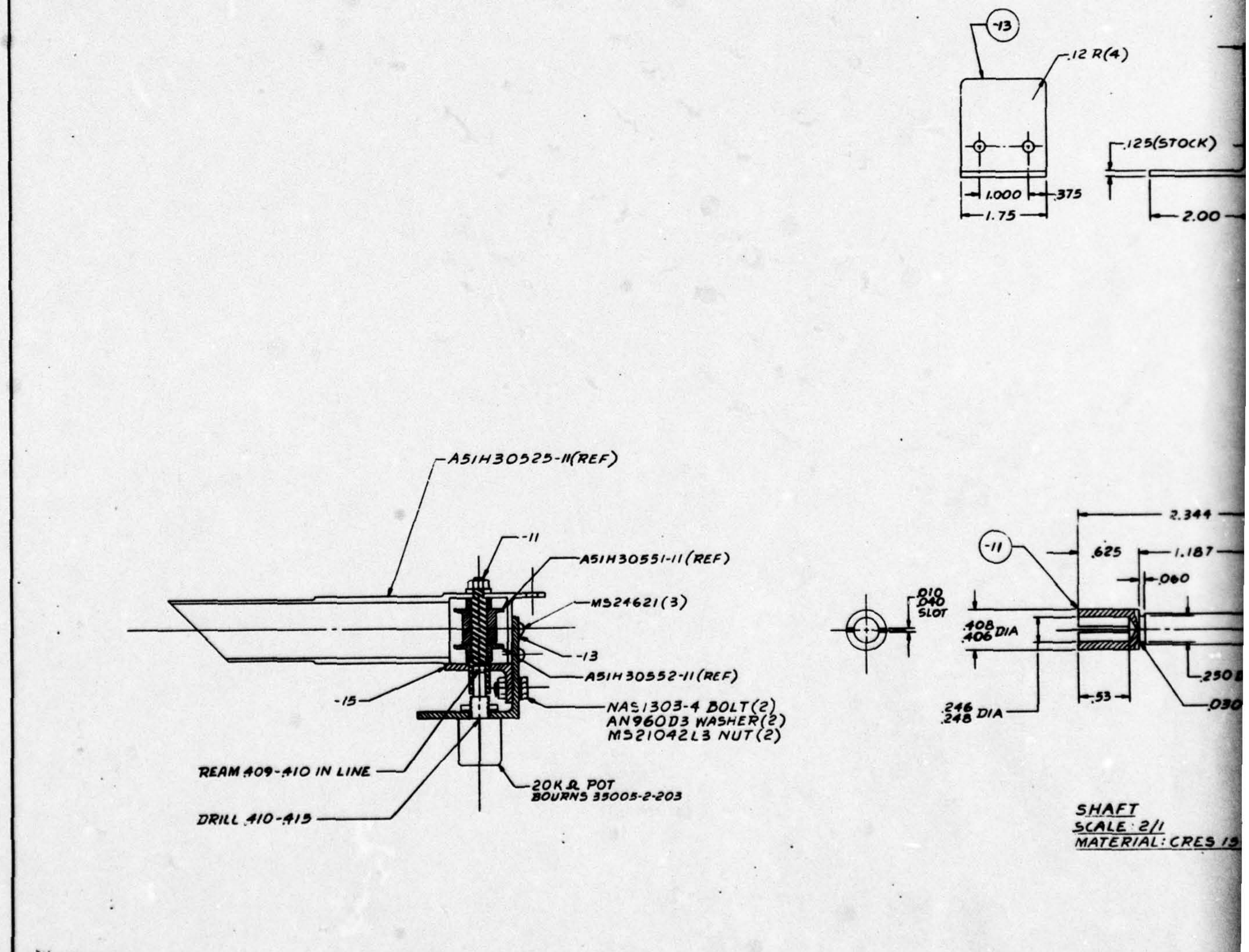
Cable..................... Stainless Steel

50

APPENDIX G

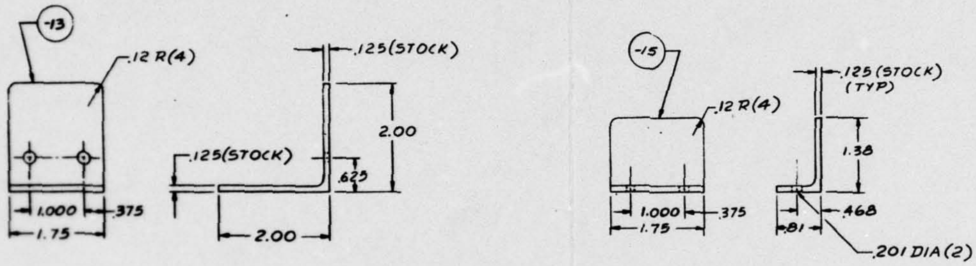
HYCOS DRAWINGS

PART NUMBER	TITLE
1491901-301	Reservoir, Combined Hydraulic System Sensor Level Remote Indicating
302	Pneumatic Bottle Fitting Modification, Kidde P/N 292659
303	Probe, Pneumatic Bottle Pressure
304	Sensor, Optical Desiccant
305	Accumulator, Hall Effect Sensor
306	Reservoir Level Sensor, A6 Remote
307	Sensor, Liquid, Pneumatic Bottle
308	Pneumatic Reservoir, Liquid Sensor
309	Sensor Pneumatic Reservoir (30 in.^{3})
310	Accumulator Installation (50 in.^{3})
311	Pneumatic Reservoir, Remote Sensing (15 in.^{3})
312	Fitting, Temperature Probe
313	Accumulator, Piston Displacement Sensor, Optical
314	Piston, Accumulator Modification (50 in.^{3})
315	Washer, Accumulator Modification (50 in.^{3})

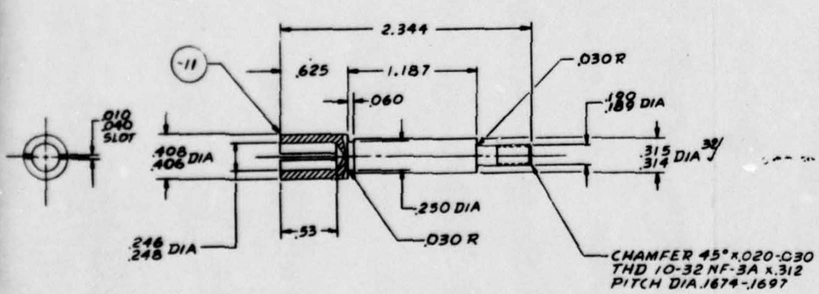


-13
.12 R(4)
.125(STOCK)
1.000
.375
1.75
2.00
A51H30525-11(REF)
-11
A51H30551-11(REF)
MS24621(3)
-13
A51H30552-11(REF)
-15
NAS1303-4 BOLT(2)
AN960D3 WASHER(2)
MS21042L3 NUT(2)
REAM .409-.410 IN LINE
20K Ω POT
BOURNS 3300S-2-203
DRILL .410-.415
.010
.040
SLOT
2.344
-11
.625
1.187
.060
.408
.406 DIA
.53
.246
.248 DIA
SHAFT
SCALE 2/1
MATERIAL: CRES 1

1087-097(1)W

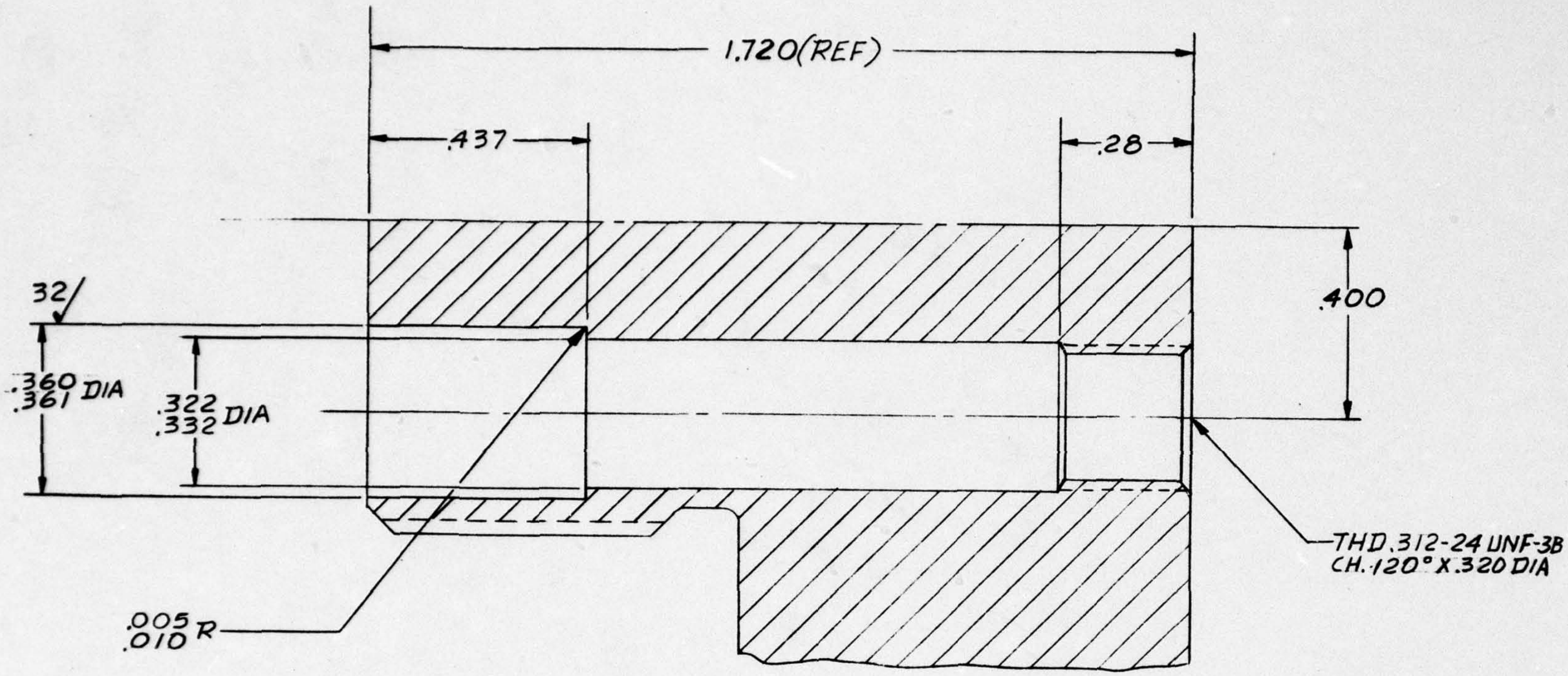


MATERIAL: GS180A25DG(7075-T6511)



SHAFT
SCALE 2/1
MATERIAL: CRES 15-5 PH

1491901-301 RESERVOIR, COMBINED
HYD. SYSTEM - SENSOR LEVEL
REMOTE INDICATING



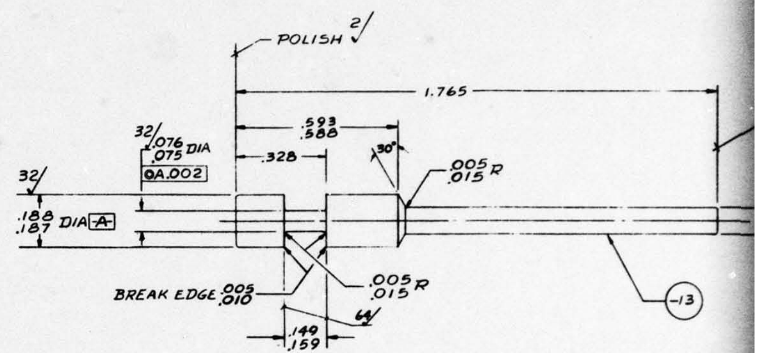
SCALE = 5-1

PROBE PORT MODIFICATION

REF KIDDE 292659 REV B

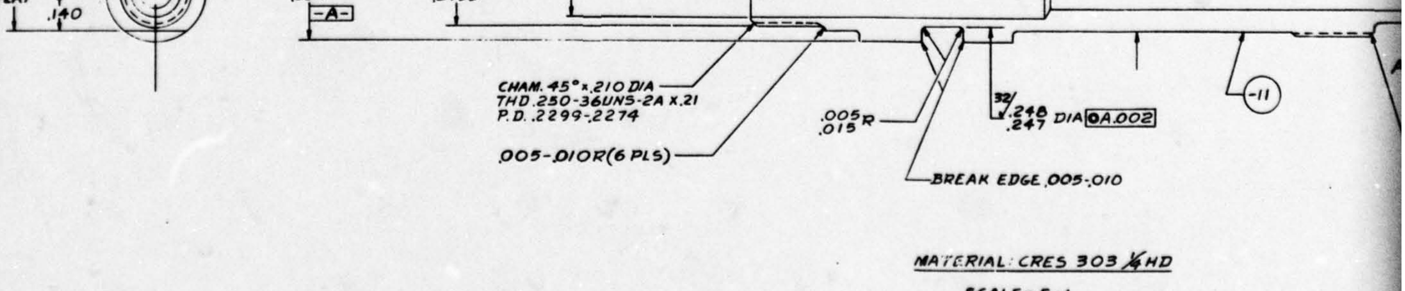
GAC 1491901-302

1087-097(2)W



MATERIAL: ACRYLIC ROD (.250 DIA) CLEAR
L-P-391, ITEM B, TYPE I

SCALE = 5-1



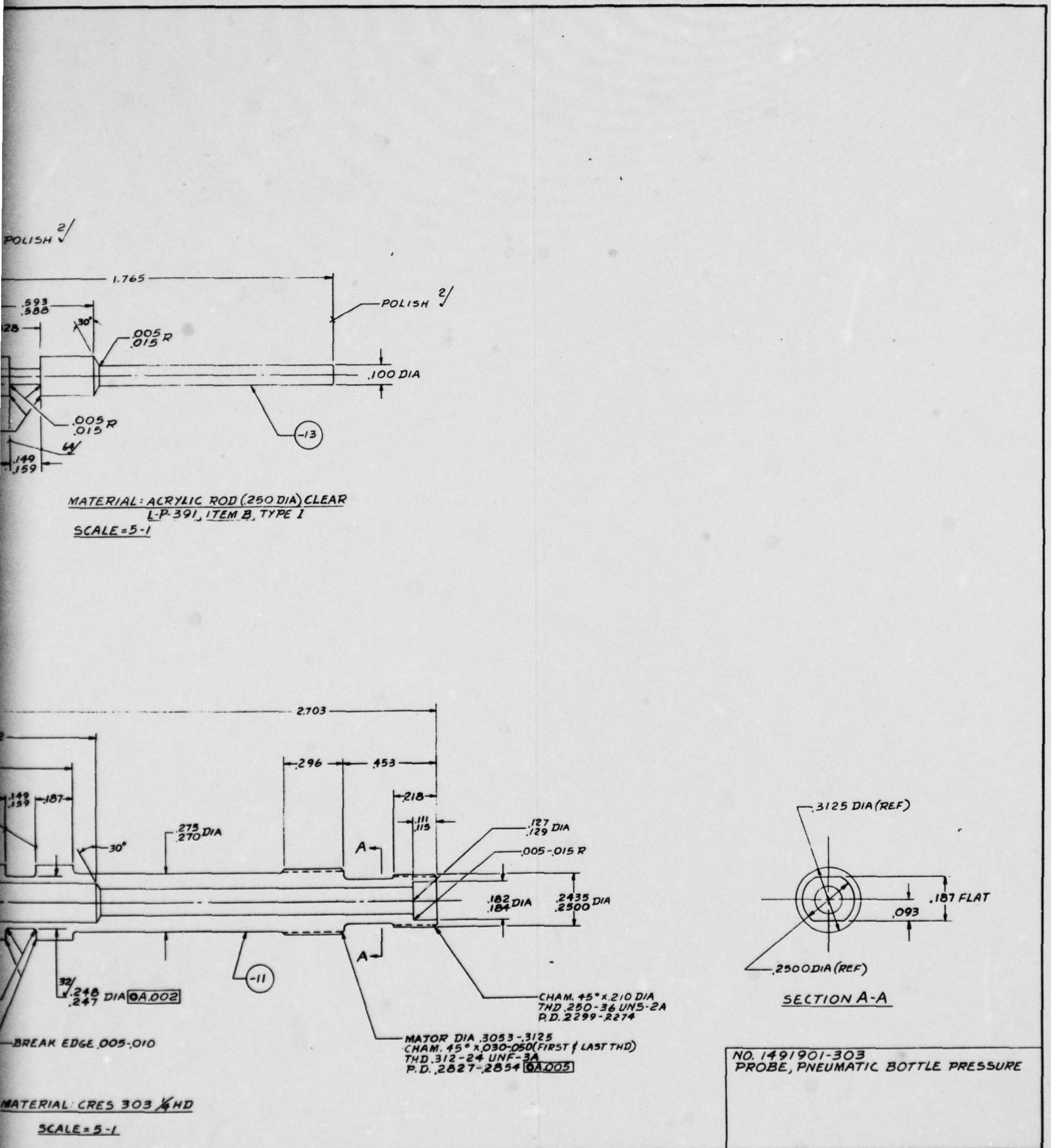
MATERIAL: CRES 303 ¼ HD

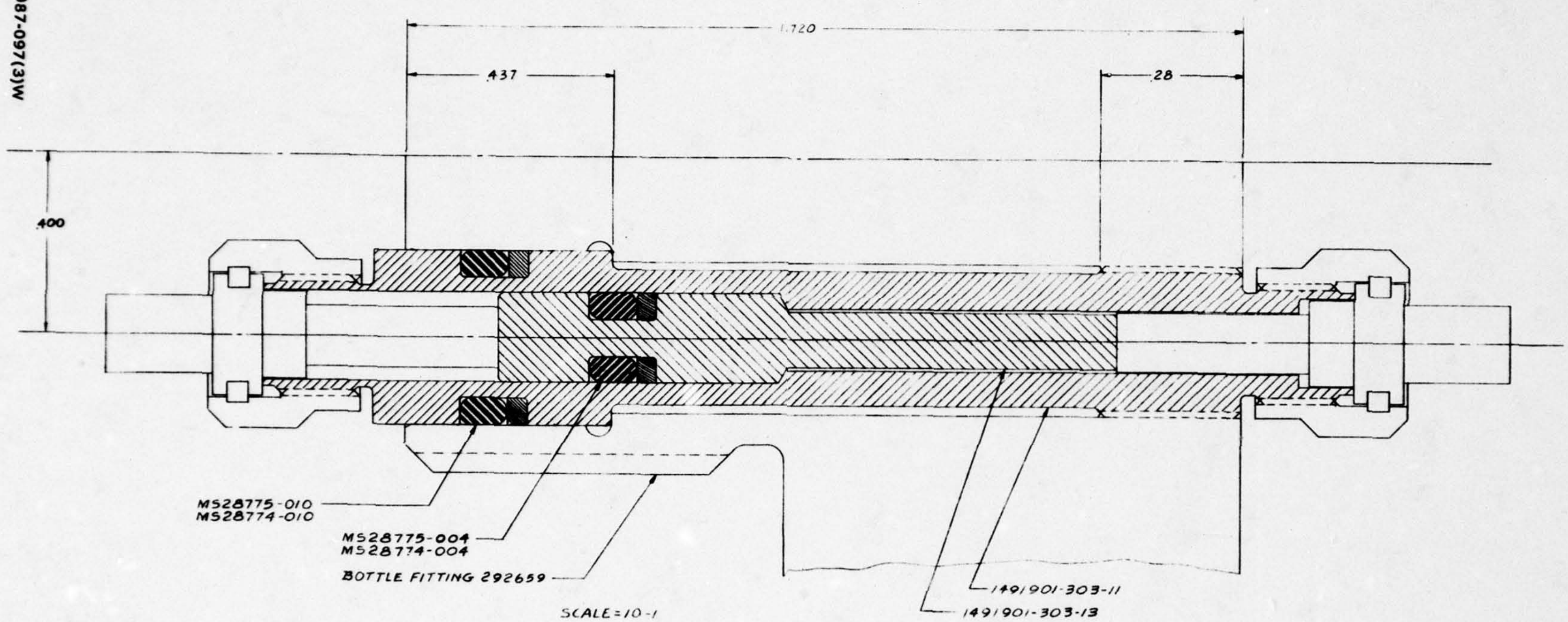
SCALE = 5-1

1087-097(4)W

1

2


POLISH 2/
1.765
.593
.588
30°
.005
.015 R
POLISH 2/
.100 DIA
.005
.015 R
64/
.149
.159
-13
MATERIAL: ACRYLIC ROD (250 DIA) CLEAR
L-P-391, ITEM B, TYPE I
SCALE = 5-1
2.703
.296
.453
.218
.149
.159
.187
.111
.115
.275
.270 DIA
30°
A
.127
.129 DIA
.005-.015 R
.182
.184 DIA
.2435
.2500 DIA
A
-11
32/
.248
.247 DIA A.002
BREAK EDGE .005-.010
CHAM. 45° x .210 DIA
THD .250-36 UNS-2A
P.D. .2299-.2274
MAJOR DIA .3053-.3125
CHAM. 45° x .030-.050 (FIRST & LAST THD)
THD .312-24 UNF-3A
P.D. .2827-.2854 A.005
MATERIAL: CRES 303 1/4 HD
SCALE = 5-1
.3125 DIA (REF)
.187 FLAT
.093
.2500 DIA (REF)
SECTION A-A
NO. 1491901-303
PROBE, PNEUMATIC BOTTLE PRESSURE

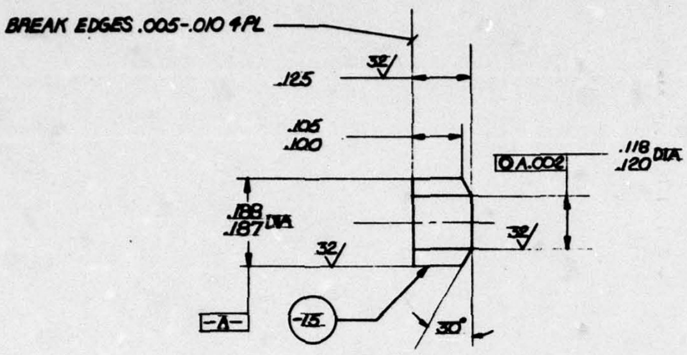


OPTICAL PRESSURE PROBE INSTALLATION

1491-901-303

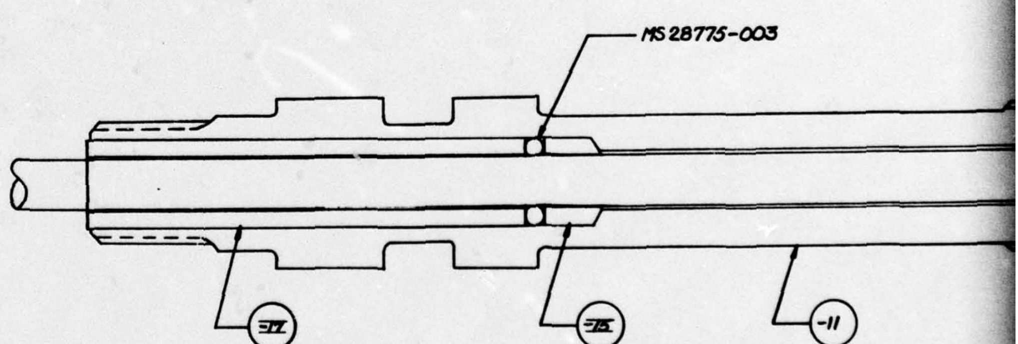
2 OF 5

1087-097(3)W



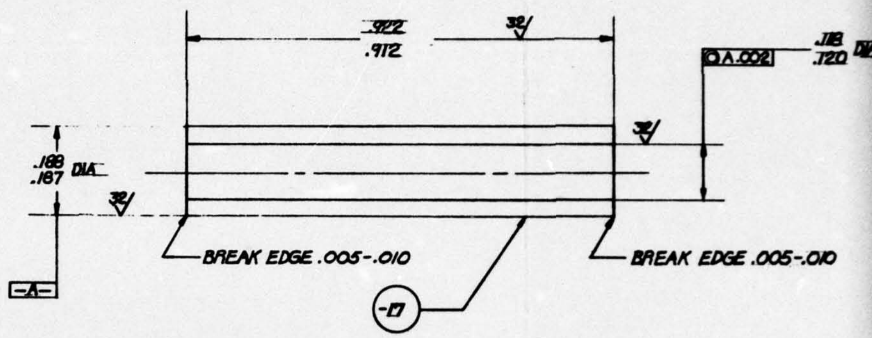
MATERIAL: TEFLON ROD (.250 DIA) BLACK

SCALE = 5-1

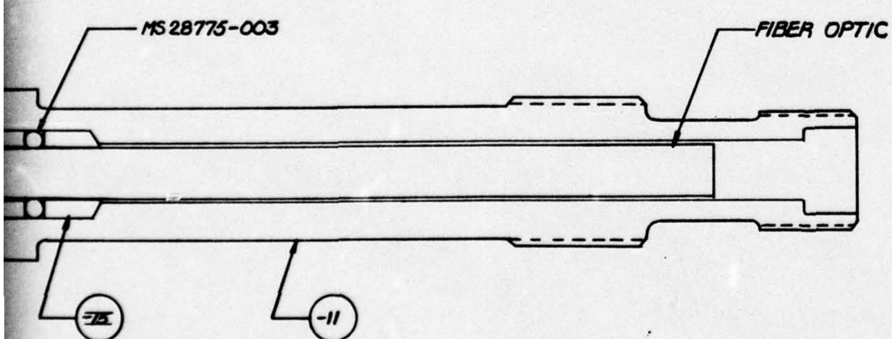


1087-097(5)W

7

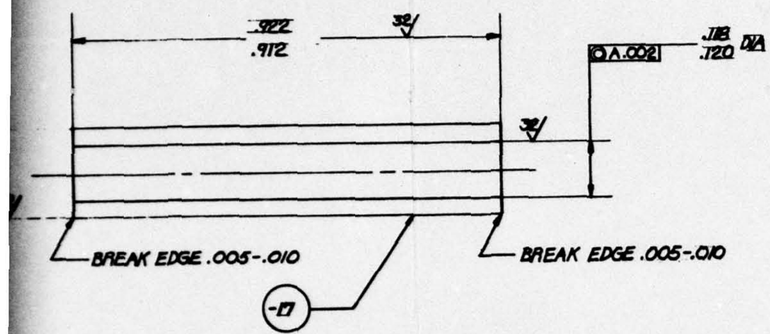


MATERIAL : CRES 303 1/4 HD (.250 DIA)
SCALE = 5-1



PROBE, PNEU
(IM

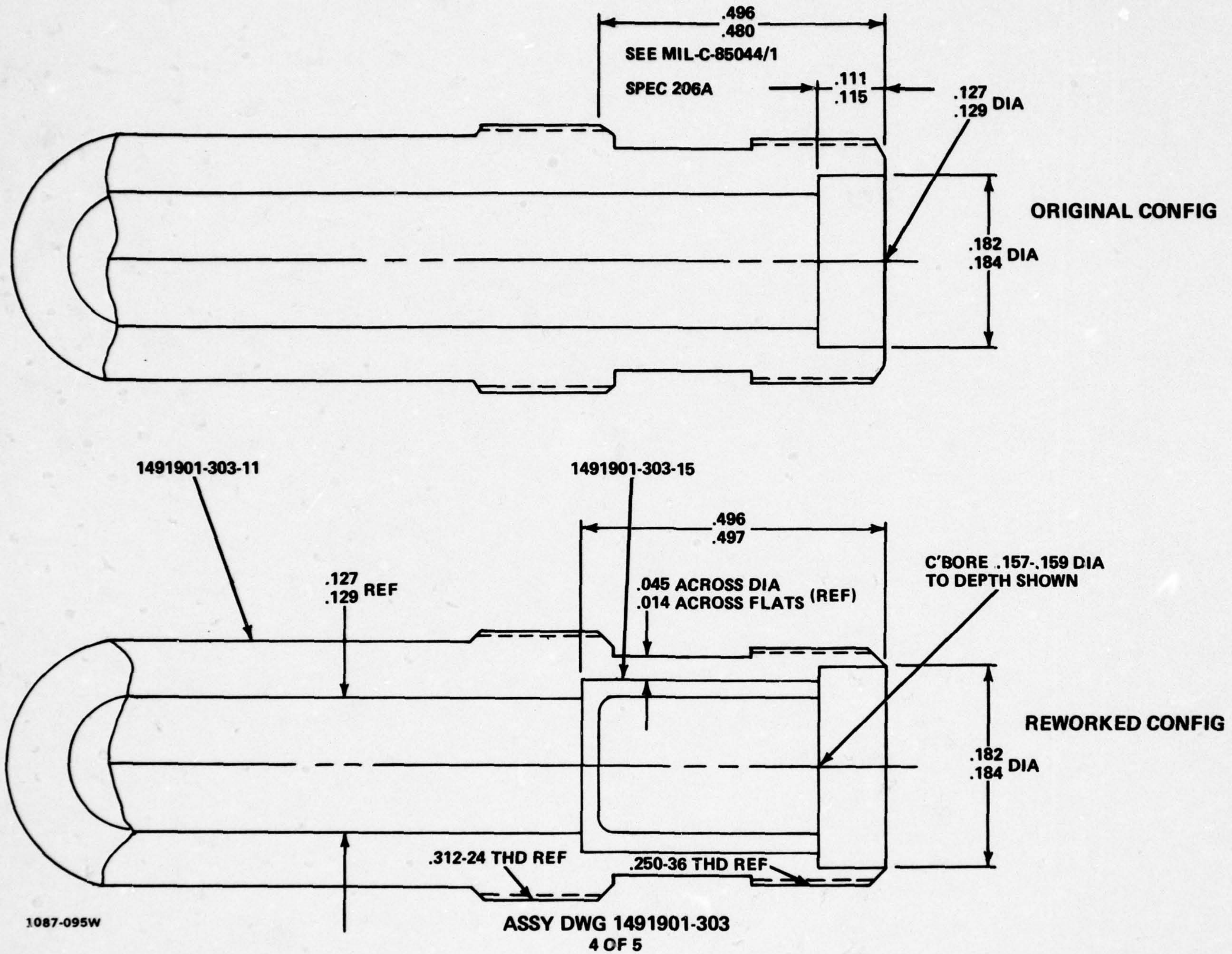
3

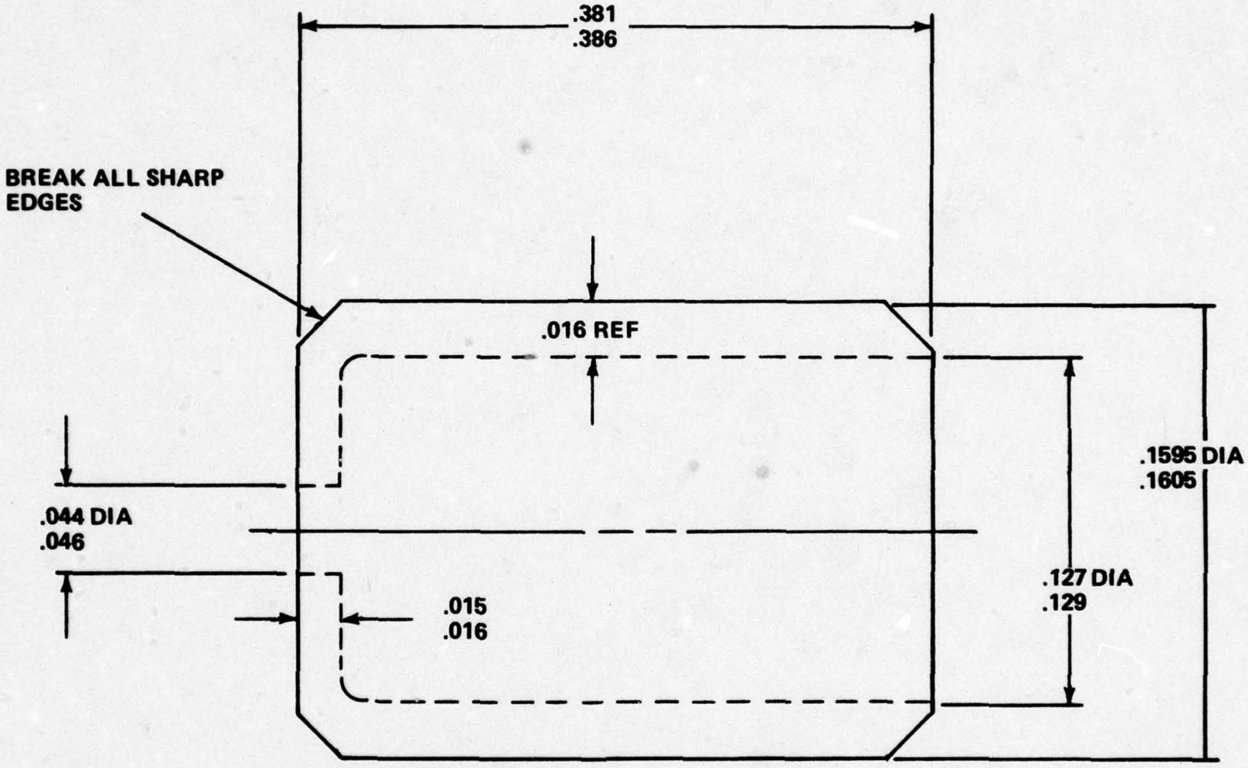


MATERIAL: CRES 303 1/4 HD (.250 DIA)
SCALE = 5-1

PTIC

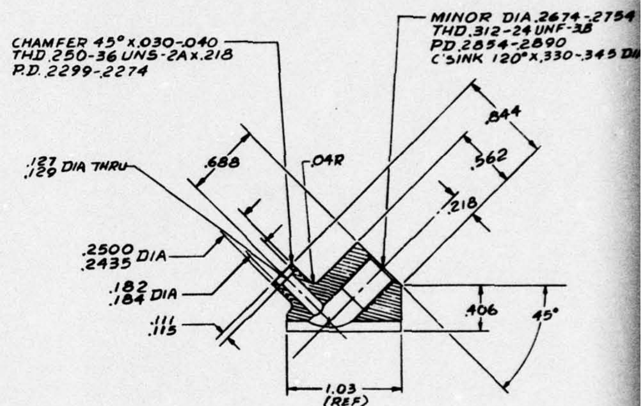
1441401-303A
PROBE, PNEUMATIC BOTTLE PRESSURE
(IMPROVED VERSION)
3 OF 5


.496
.480
SEE MIL-C-85044/1
SPEC 206A
.111
.115
.127
.129 DIA
ORIGINAL CONFIG
.182
.184 DIA
1491901-303-11
1491901-303-15
.496
.497
C'BORE .157-.159 DIA
TO DEPTH SHOWN
.127
.129 REF
.045 ACROSS DIA
.014 ACROSS FLATS (REF)
REWORKED CONFIG
.182
.184 DIA
.312-24 THD REF
.250-36 THD REF
1087-095W
ASSY DWG 1491901-303
4 OF 5

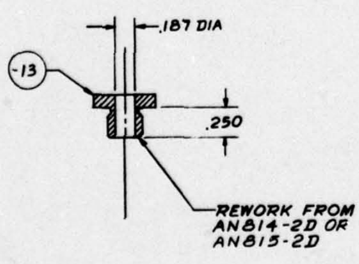


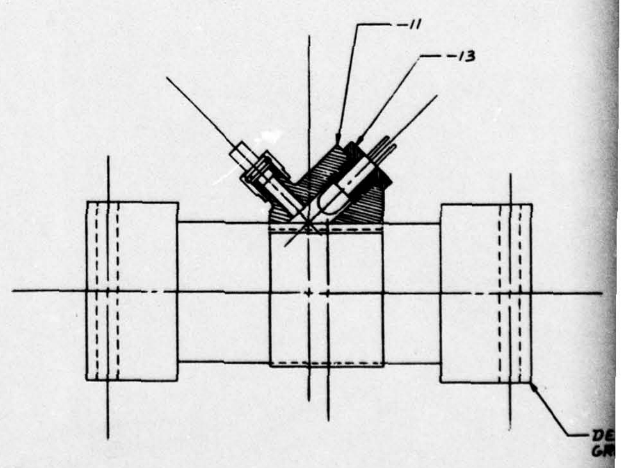
NO. 1491901-303-15
MATL: CRES 303 ¼ HD
NO SCALE

1087-094W



MATERIAL: AL
SCALE = 2-1

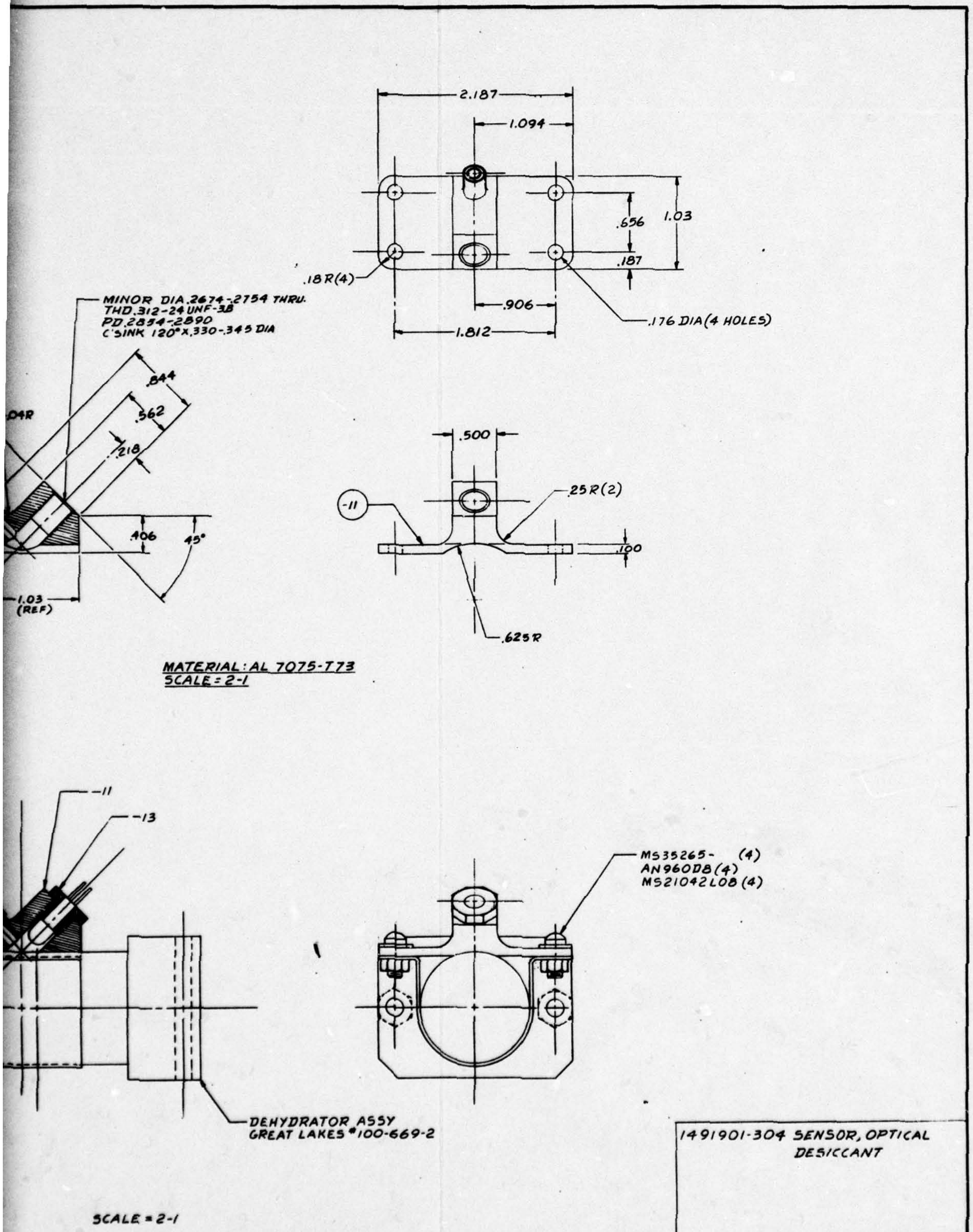




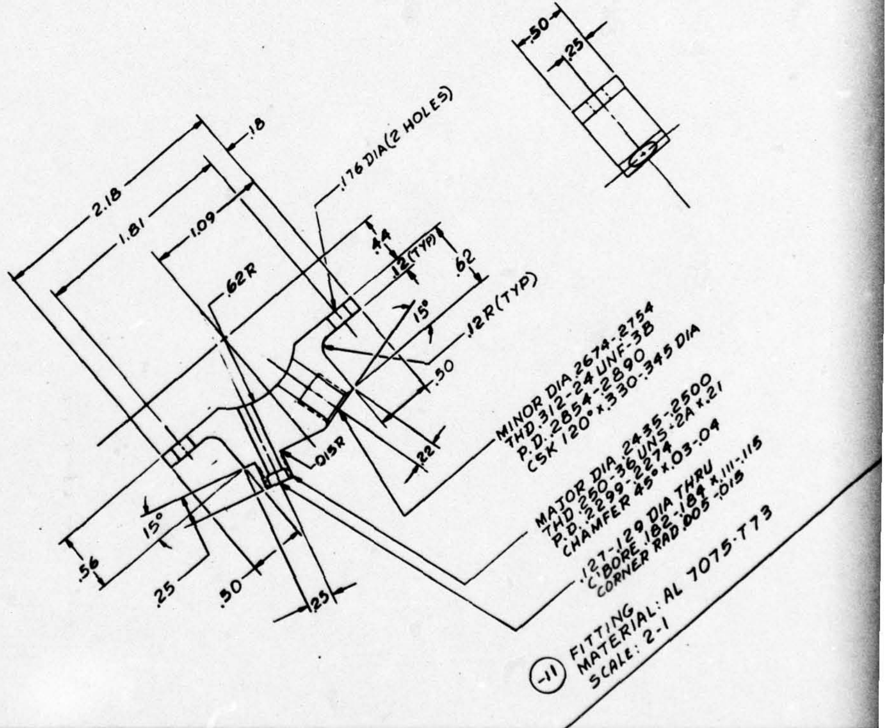
1087-097(6)W

SCALE = 2-1

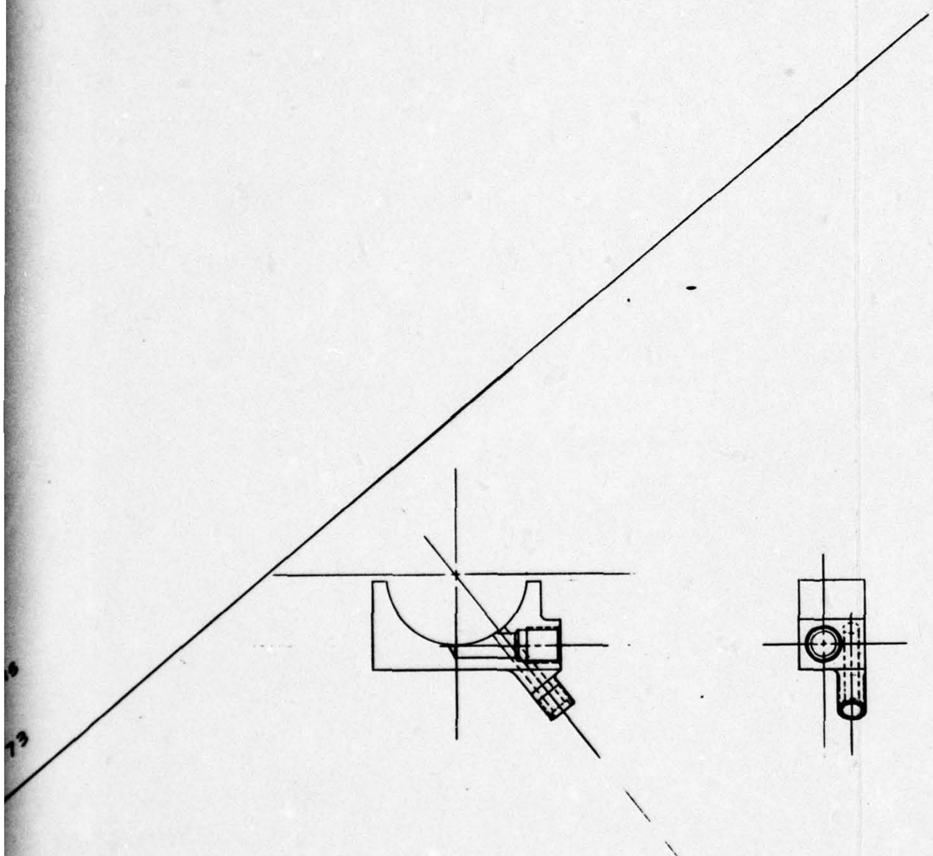
2



1491901-304 SENSOR, OPTICAL
DESICCANT

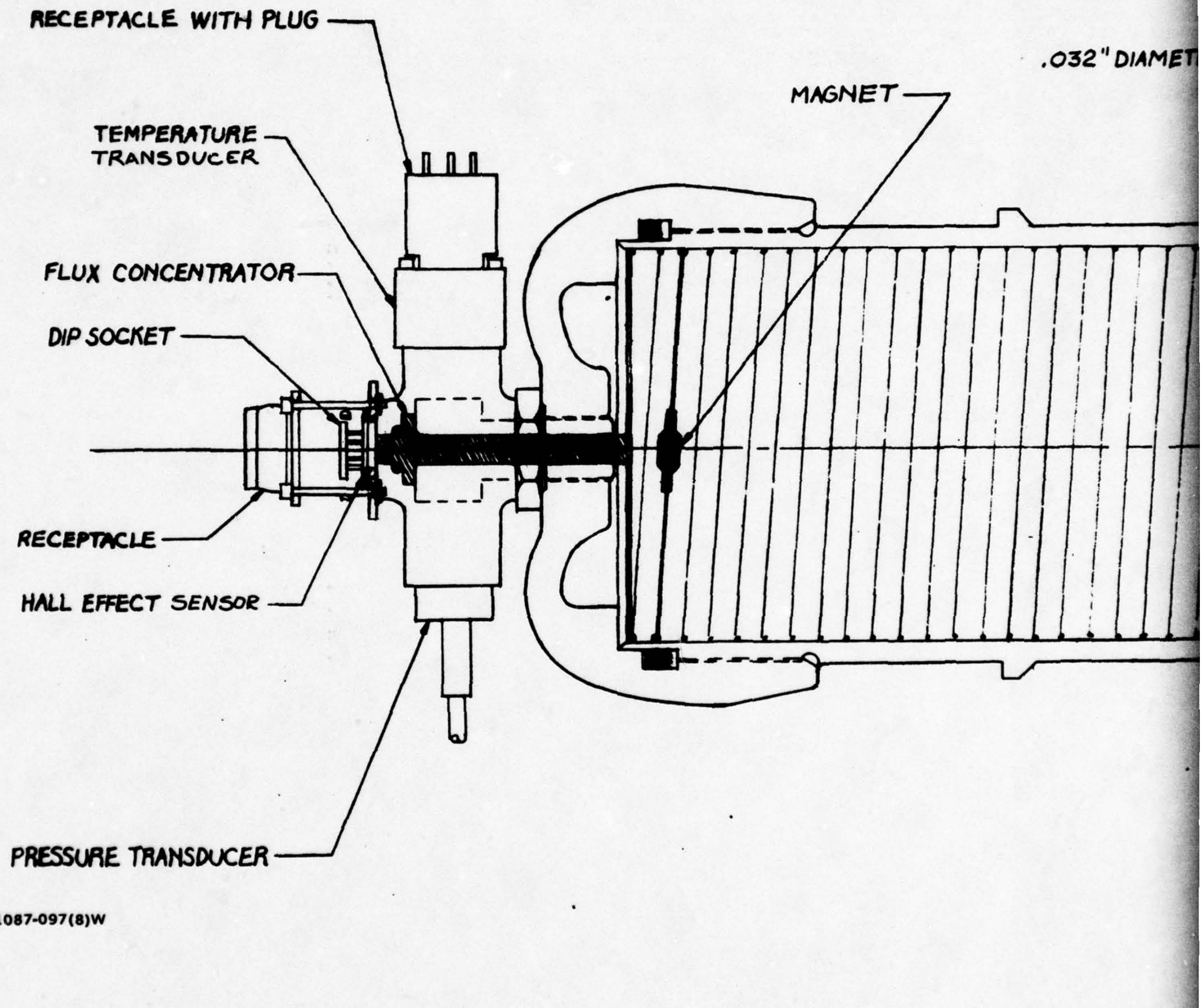

.50
.25
2.18
1.81
1.09
.18
.176 DIA (2 HOLES)
.44
.12 (TYP)
.62
.62R
15°
.12R (TYP)
.50
.22
.015R
15°
.56
.25
.50
.25
MINOR DIA .2674-.2754
THD .312-24 UNF-3B
P.D. .2854-.2890
CSK 120° x .330-.345 DIA
MAJOR DIA .2435-.2500
THD .250-36 UNS-2A x .21
P.D. .2299-.2274
CHAMFER 45° x .03-.04
.127-.129 DIA THRU
C'BORE .182-.184 x .111-.115
CORNER RAD .005-.015
-11 FITTING
MATERIAL: AL 7075-T73
SCALE: 2-1

1087-097(7)W



FOR PARTS LIST, USAGE DATA, AND DWG SH STATUS, SEE DOCUMENT SAME NUMBER PREFIXED PL.

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES LINEAR TOL .XX ± .03 .XXX ± .010 ANGULAR TOL ± 0°30' TOL ON LOFTED DELINEATIONS IS	CONTRACT NO. DRAWN BY LAYOUT BY CHECKED BY GR LEADER REL GROUP PROJ ENGR GOVT APPD	GRUMMAN AEROSPACE CORPORATION BETHPAGE, NEW YORK 11714 SENSOR, OPTICAL DESICCANT SIZE A CODE IDENT NO. 26512 1491901-304 SCALE SHEET 2 OF 2

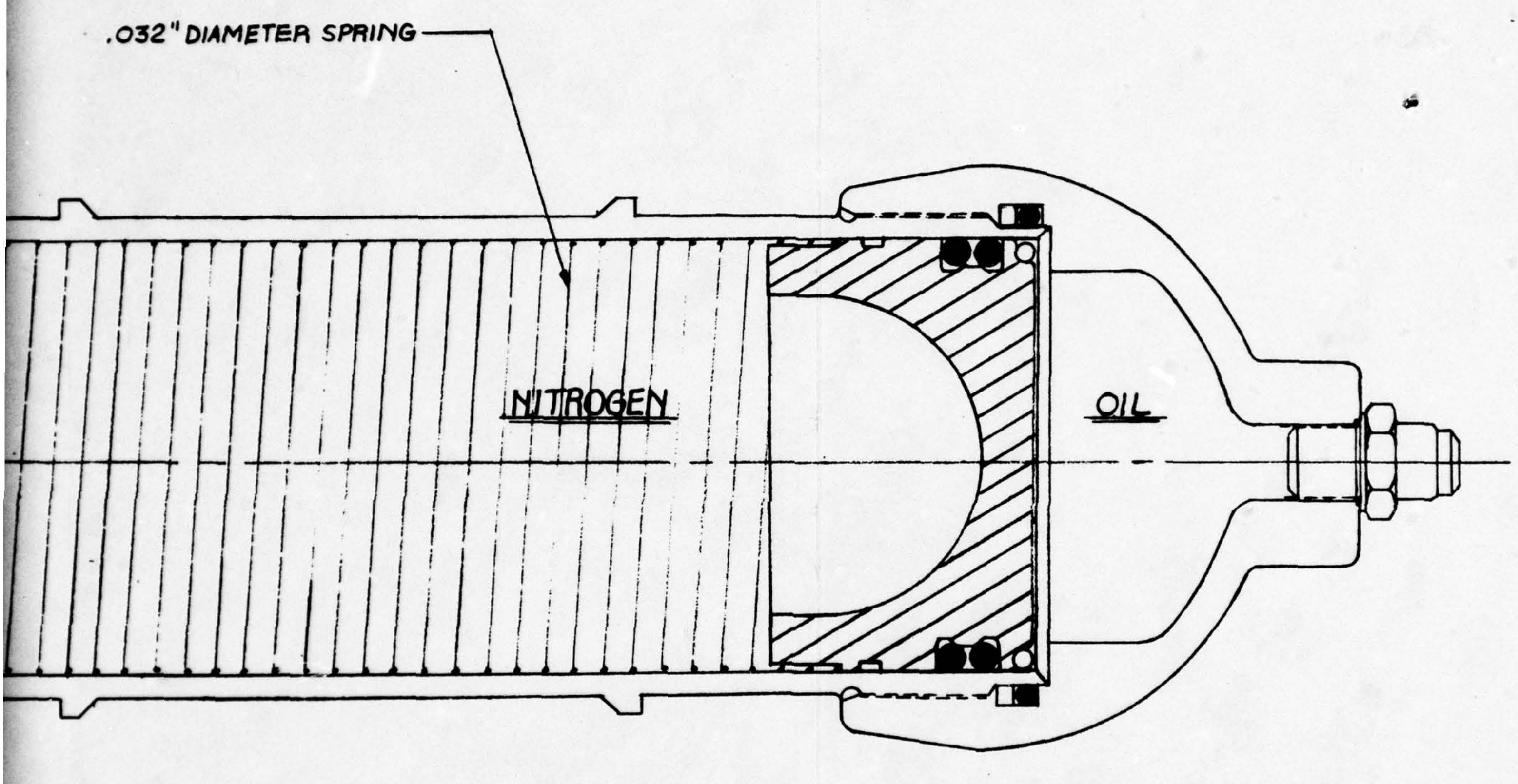


RECEPTACLE WITH PLUG
.032" DIAMET
MAGNET
TEMPERATURE TRANSDUCER
FLUX CONCENTRATOR
DIP SOCKET
RECEPTACLE
HALL EFFECT SENSOR
PRESSURE TRANSDUCER

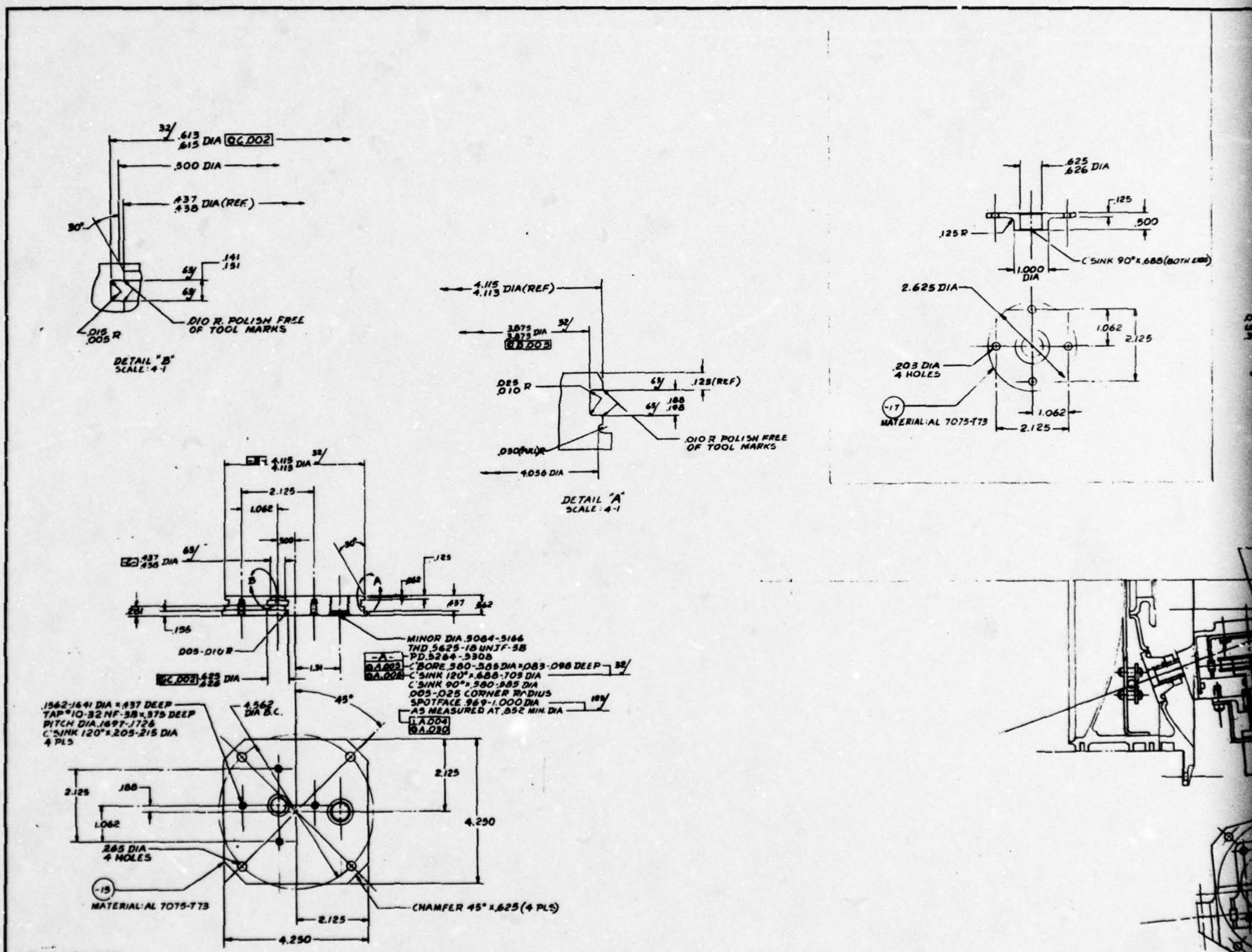
1087-097(8)W

1

2



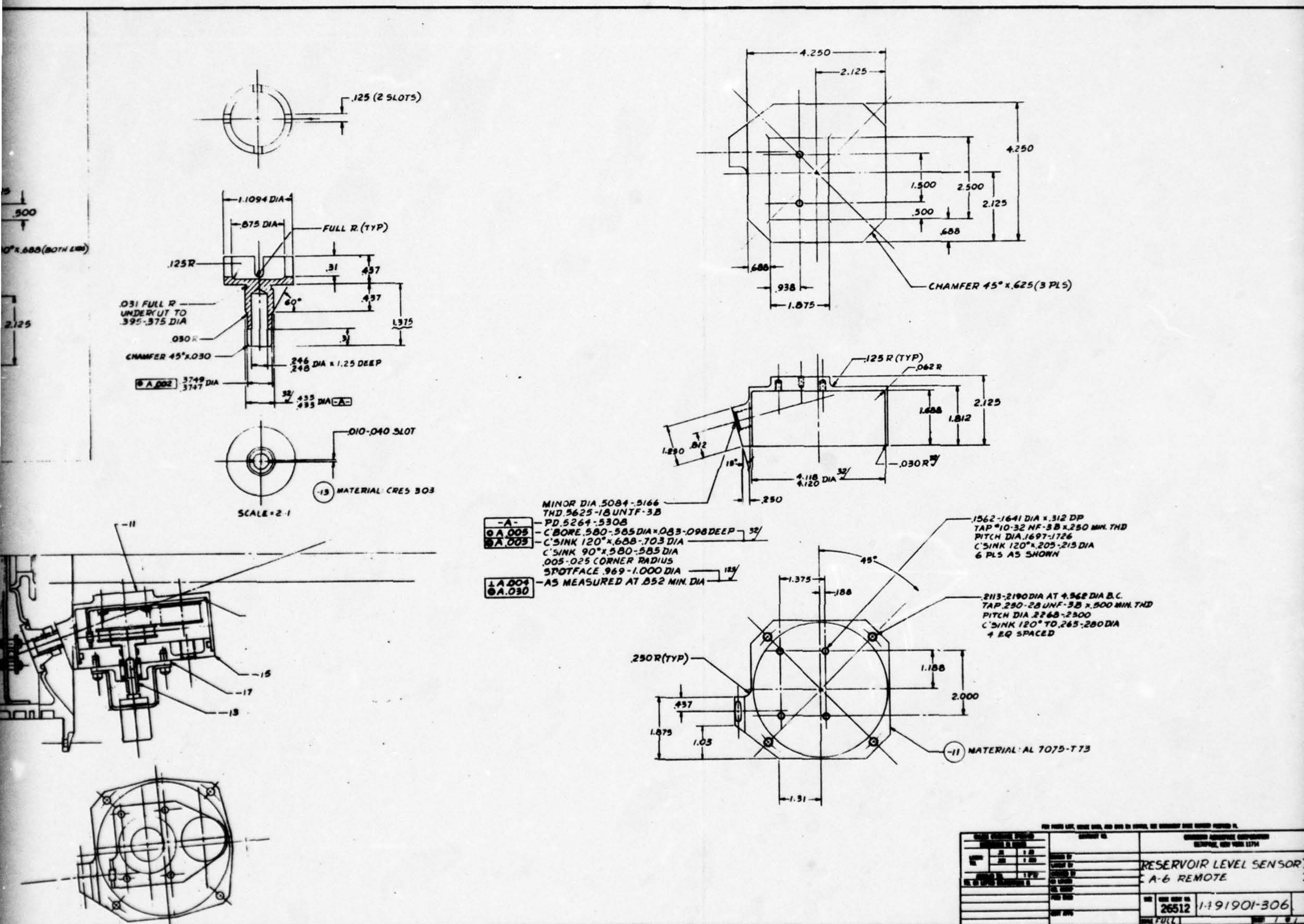
ACCUMULATOR, LINEAR DISPLACEMENT HALL EFFECT SENSOR (CONCEPT)
1491-901-305

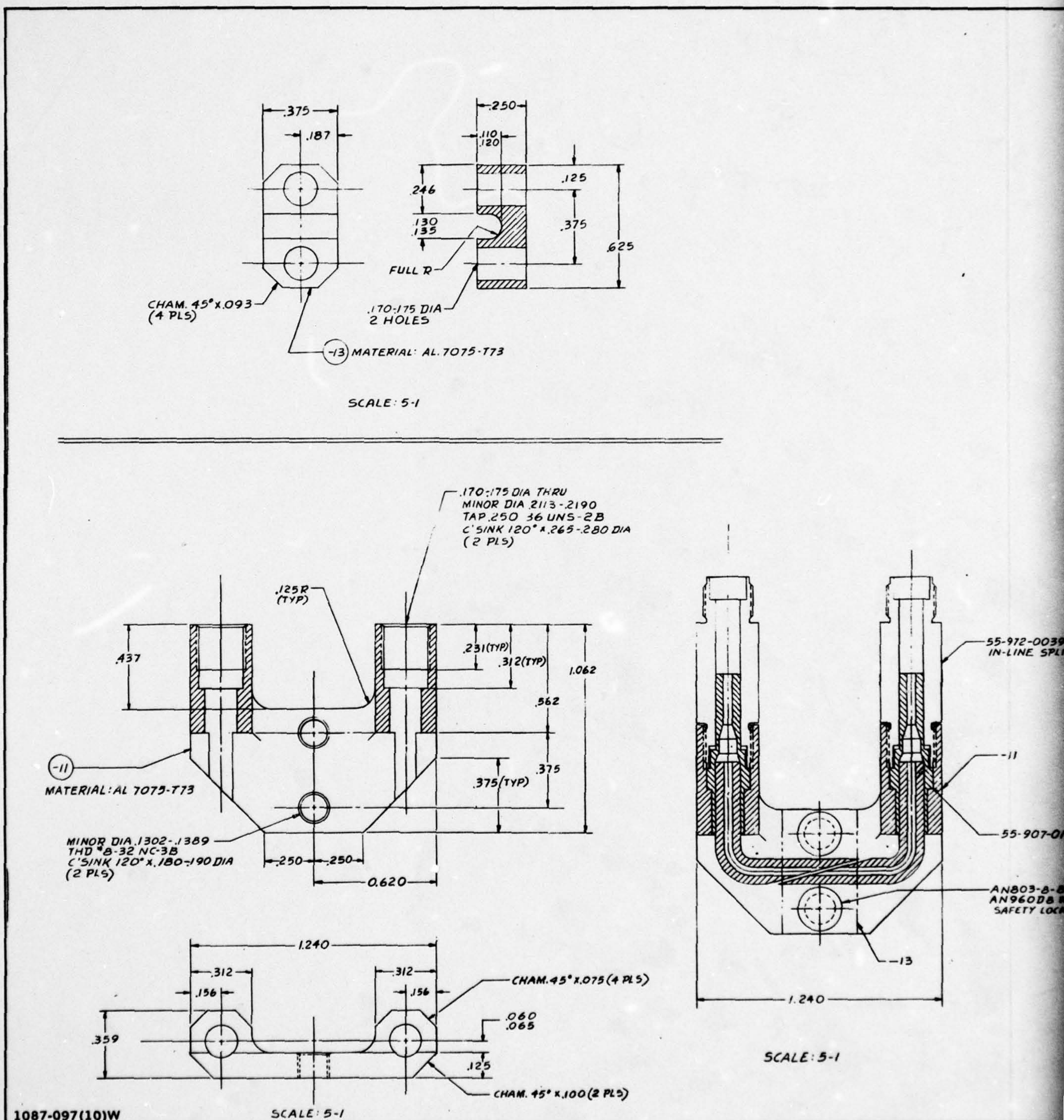

.613 .615 DIA
.500 DIA
.437 .438 DIA (REF.)
30°
.141 .151
.010 R. POLISH FREE OF TOOL MARKS
.015 .005 R
DETAIL "B"
SCALE: 4-1
4.115 4.113 DIA (REF.)
.125 (REF)
.188 .198
.025 R .010
.010 R POLISH FREE OF TOOL MARKS
4.056 DIA
DETAIL "A"
SCALE: 4-1
.625 .626 DIA
.125
.500
.125 R
1.000 DIA
C'SINK 90° x .688 (BOTH ENDS)
2.625 DIA
1.062
2.125
.203 DIA 4 HOLES
-17
MATERIAL: AL 7075-T73
4.115 4.113 DIA
2.125
1.062
.300
.437 .438 DIA
.125
.156
.005-.010 R
1.31
MINOR DIA .5084-.5166
THD .5625-18 UNJF-3B
P.D. .5264-.5308
C'BORE .380-.385 DIA x .083-.098 DEEP
C'SINK 120° x .688-.703 DIA
C'SINK 90° x .380-.385 DIA
.005-.025 CORNER RADIUS
SPOTFACE .969-1.000 DIA
AS MEASURED AT .852 MIN. DIA
.1562-.1641 DIA x .437 DEEP
TAP #10-32 NF-3B x .375 DEEP
PITCH DIA .1697-.1726
C'SINK 120° x .205-.215 DIA
4 PLS
4.562 DIA B.C.
45°
2.125
.188
1.062
4.250
.265 DIA 4 HOLES
-15
MATERIAL: AL 7075-T73
CHAMFER 45° x .625 (4 PLS)
2.125
4.250

1087-097(9)W

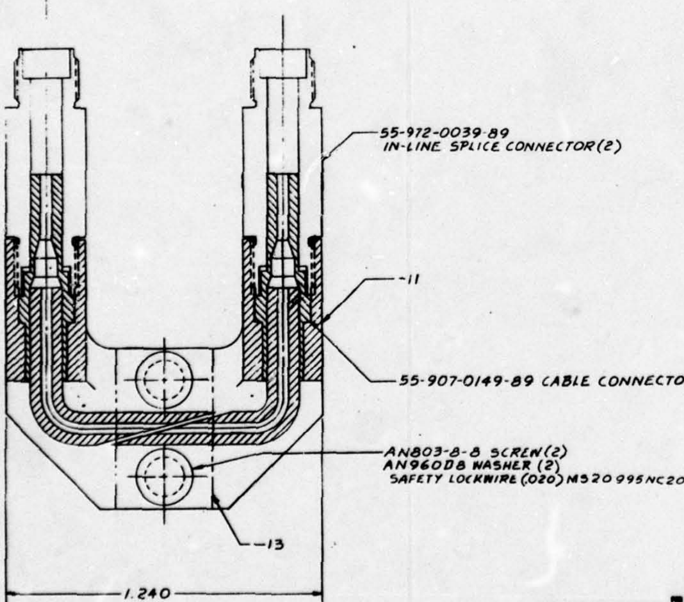
1

2


.125 (2 SLOTS)
1.1094 DIA
.875 DIA
FULL R (TYP)
.125R
.31
.437
.437
60°
1.375
.031 FULL R UNDERCUT TO .395-.375 DIA
.030 R
CHAMFER 45° x .030
.246 .248 DIA x 1.25 DEEP
.3749 .3747 DIA
.435 .433 DIA
.010-.040 SLOT
-13 MATERIAL: CRES 303
SCALE = 2:1
4.250
2.125
4.250
1.500
2.500
2.125
.500
.688
.688
.938
1.875
CHAMFER 45° x .625 (3 PLS)
.125 R (TYP)
.062 R
2.125
1.688
1.812
1.290
.812
15°
4.118 4.120 DIA
.030 R
.250
MINOR DIA .5084-.5166
THD .5625-18 UNJF-3B
PD .5264-.5308
C'BORE .580-.585 DIA x .083-.098 DEEP
C'SINK 120° x .688-.703 DIA
C'SINK 90° x .580-.585 DIA
.005-.025 CORNER RADIUS
SPOTFACE .969-1.000 DIA
AS MEASURED AT .852 MIN. DIA
.1562-.1641 DIA x .312 DP
TAP #10-32 NF-3B x .250 MIN. THD
PITCH DIA .1697-.1726
C'SINK 120° x .205-.215 DIA
6 PLS AS SHOWN
45°
1.375
.188
.2113-.2190 DIA AT 4.962 DIA B.C.
TAP .250-28 UNF-3B x .500 MIN. THD
PITCH DIA .2268-.2300
C'SINK 120° TO .265-.280 DIA
4 EQ SPACED
.250 R (TYP)
1.188
2.000
.437
1.875
1.03
1.31
-11 MATERIAL: AL 7075-T73
-11
-15
-17
-13
RESERVOIR LEVEL SENSOR
A-6 REMOTE
26512
1-191901-306
FULL


.375
.187
.250
.110
.120
.125
.246
.130
.135
.375
.625
FULL R
CHAM. 45° x.093
(4 PLS)
.170-.175 DIA
2 HOLES
-13 MATERIAL: AL.7075-T73
SCALE: 5-1
.170-.175 DIA THRU
MINOR DIA .2113-.2190
TAP .250 36 UNS-2B
C'SINK 120° x .265-.280 DIA
(2 PLS)
.125R
(TYP)
.437
.231(TYP)
.312(TYP)
1.062
.562
-11
MATERIAL: AL 7075-T73
.375(TYP)
.375
MINOR DIA .1302-.1389
THD #8-32 NC-3B
C'SINK 120° x .180-.190 DIA
(2 PLS)
.250
.250
0.620
1.240
.312
.312
.156
.156
CHAM. 45° x.075 (4 PLS)
.359
.060
.065
.125
CHAM. 45° x.100 (2 PLS)
SCALE: 5-1
55-972-0039-
IN-LINE SPLI
-11
55-907-0
AN803-8-8
AN960D8
SAFETY LOC
-13
1.240
SCALE: 5-1
1087-097(10)W

2

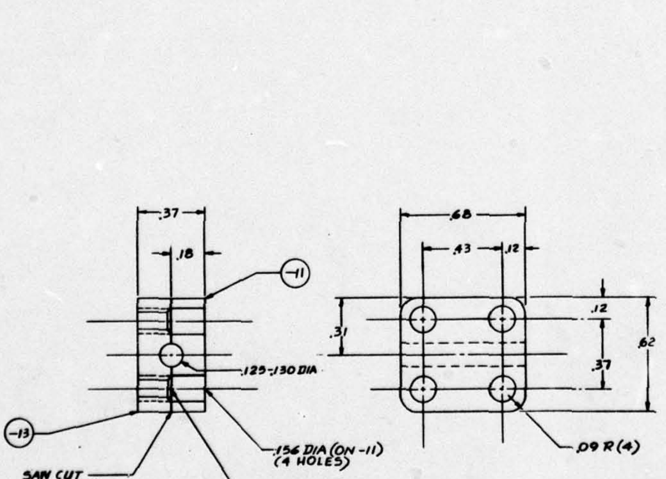


SCALE: 5-1

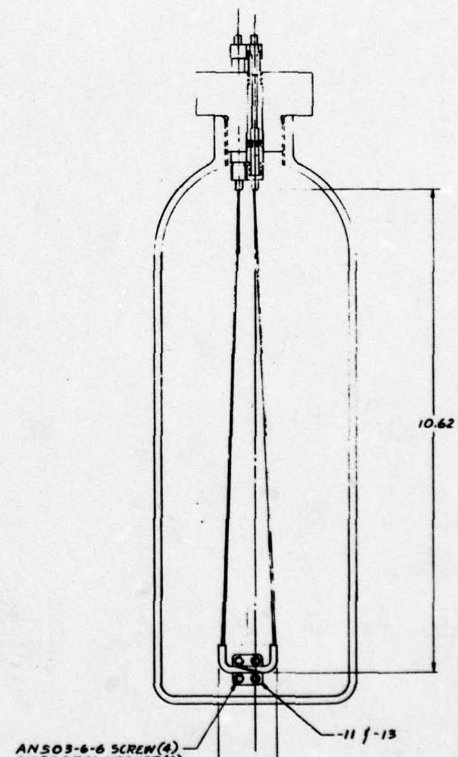
SENSOR, LIQUID
PNEUMATIC BOTTLE

26512 1491901-307

SCALE 5-1 SHEET 1 of 1

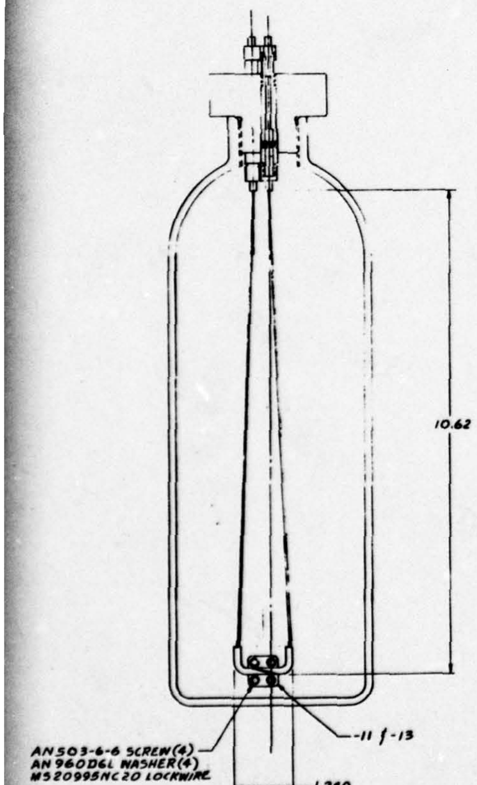


MATERIAL: AL 7075-T73
SCALE = 4-1



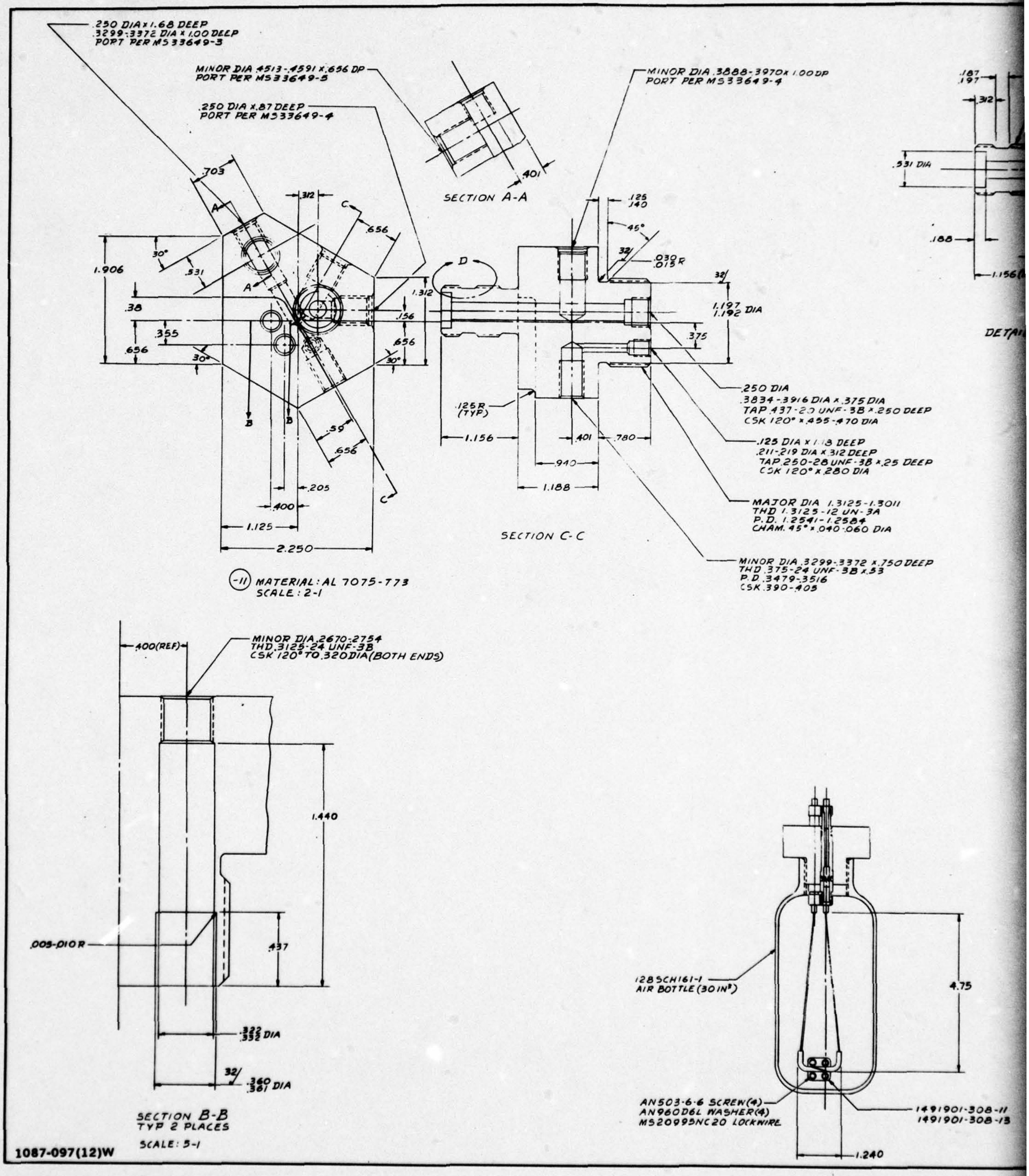
1087-097(11)W

2



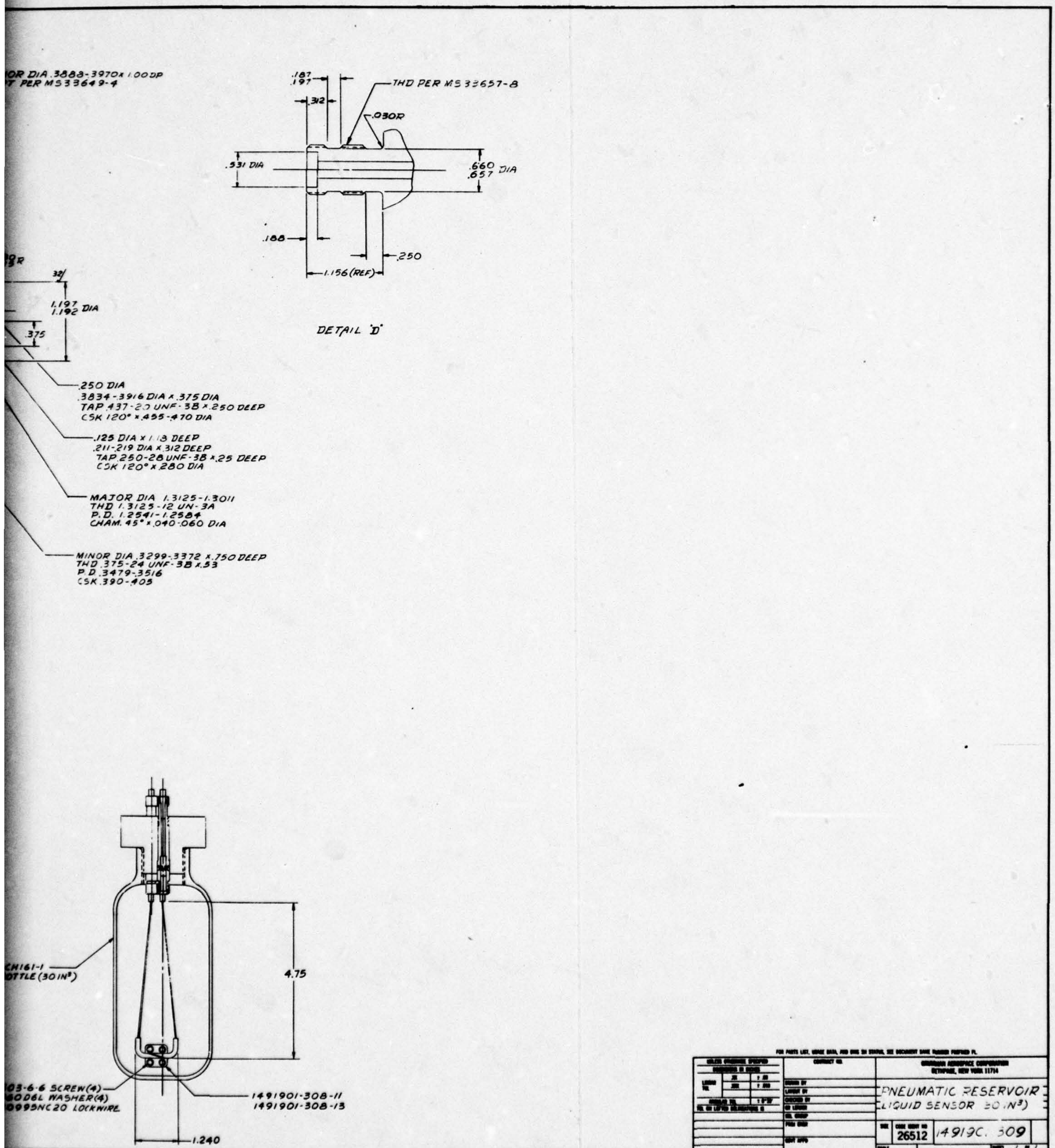
PNEUMATIC RESERVOIR
LIQUID SENSOR

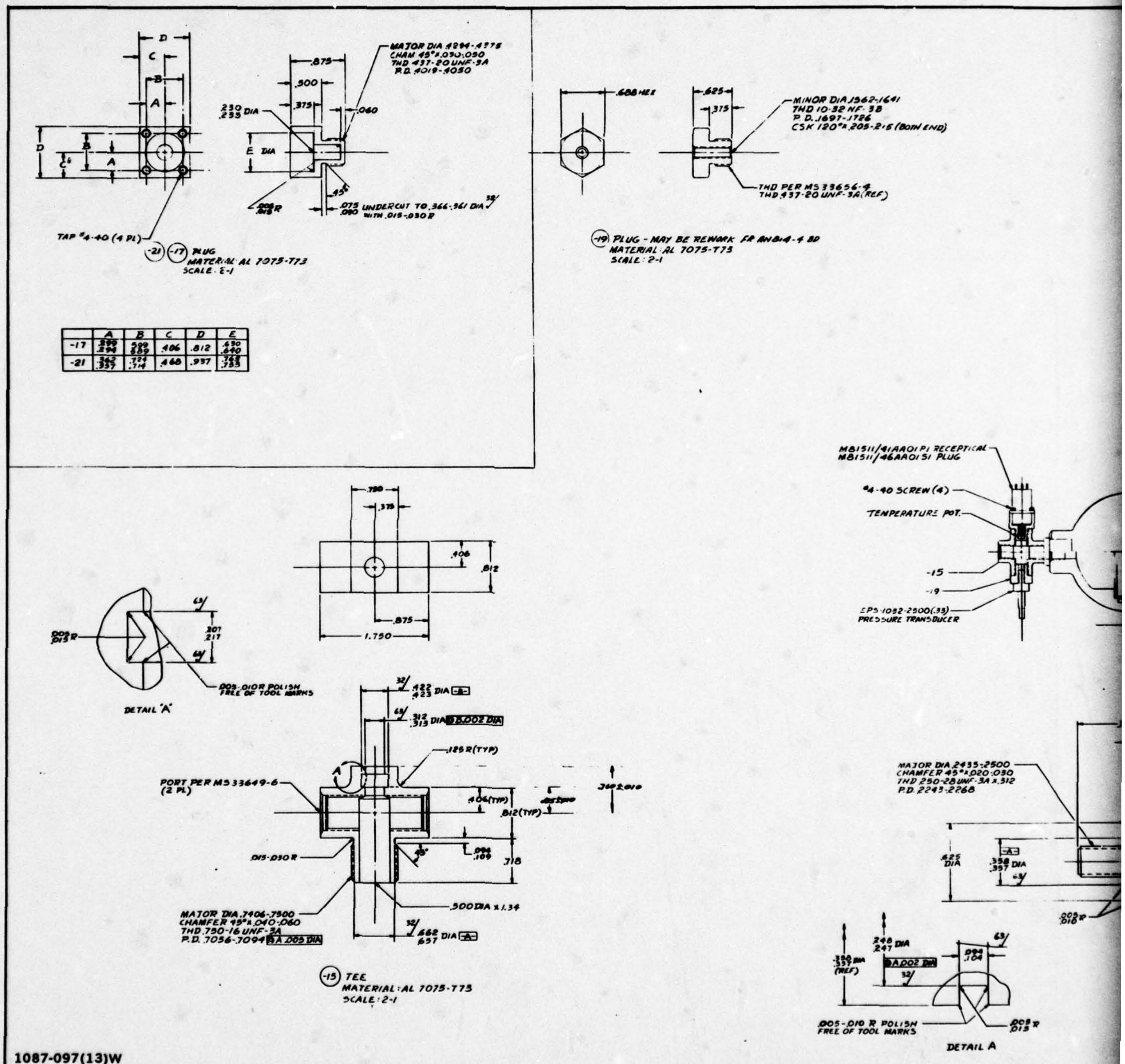
26512 1491901-308


.250 DIA x 1.68 DEEP
.3299-.3372 DIA x 1.00 DEEP
PORT PER MS33649-3
MINOR DIA .4513-.4591 x .656 DP
PORT PER MS33649-5
.250 DIA x .87 DEEP
PORT PER MS33649-4
MINOR DIA .3888-.3970 x 1.00 DP
PORT PER MS33649-4
SECTION A-A
SECTION C-C
.250 DIA
.3834-.3916 DIA x .375 DIA
TAP .437-20 UNF-3B x .250 DEEP
CSK 120° x .455-.470 DIA
.125 DIA x 1.18 DEEP
.211-.219 DIA x .312 DEEP
TAP .250-28 UNF-3B x .25 DEEP
CSK 120° x .280 DIA
MAJOR DIA 1.3125-1.3011
THD 1.3125-12 UN-3A
P.D. 1.2541-1.2584
CHAM. 45° x .040-.060 DIA
MINOR DIA .3299-.3372 x .750 DEEP
THD .375-24 UNF-3B x .53
P.D. .3479-.3516
CSK .390-.405
-11 MATERIAL: AL 7075-T73
SCALE: 2-1
MINOR DIA .2670-.2754
THD .3125-24 UNF-3B
CSK 120° TO .320 DIA (BOTH ENDS)
.400(REF)
.005-.010 R
SECTION B-B
TYP 2 PLACES
SCALE: 5-1
128SCH161-1
AIR BOTTLE (30 IN³)
AN503-6-6 SCREW(4)
AN960D6L WASHER(4)
MS20995NC20 LOCKWIRE
1491901-308-11
1491901-308-13
DETAIL
1087-097(12)W

1

2

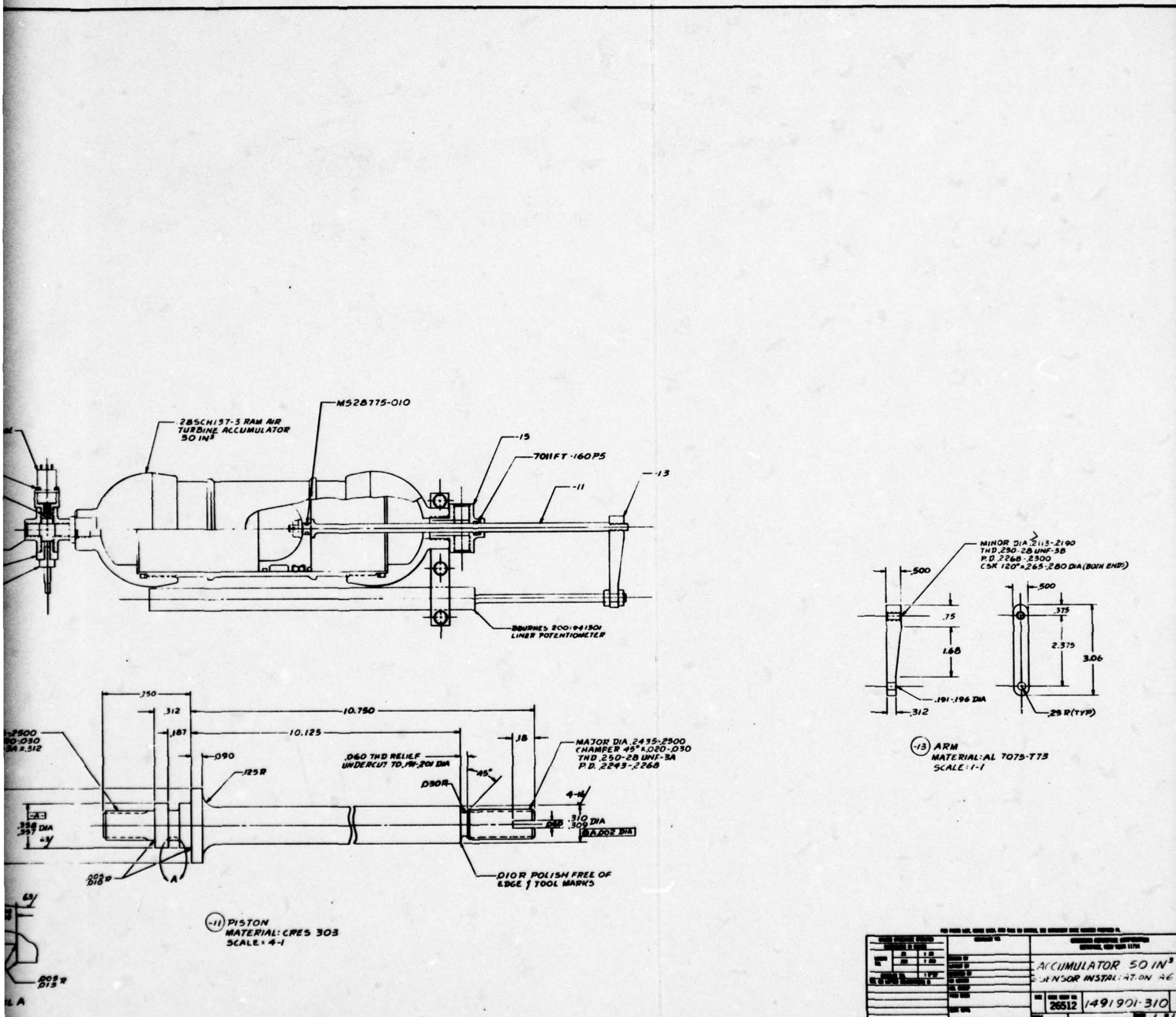

OR DIA .3888-.3970 x 1.00 DP
T PER MS33649-4
.187
.197
.312
THD PER MS33657-8
.030R
.531 DIA
.660
.657 DIA
.188
.250
1.156 (REF)
DETAIL 'D'
1.197
1.192 DIA
.375
.250 DIA
.3834-.3916 DIA x .375 DIA
TAP .437-20 UNF-3B x .250 DEEP
CSK 120° x .455-.470 DIA
.125 DIA x 1.18 DEEP
.211-.219 DIA x .312 DEEP
TAP .250-28 UNF-3B x .25 DEEP
CSK 120° x .280 DIA
MAJOR DIA 1.3125-1.3011
THD 1.3125-12 UN-3A
P.D. 1.2541-1.2584
CHAM. 45° x .040-.060 DIA
MINOR DIA .3299-.3372 x .750 DEEP
THD .375-24 UNF-3B x .53
P.D. .3479-.3516
CSK .390-.405
CH161-1
OTTLE (30 IN³)
4.75
03-6-6 SCREW(4)
S006L WASHER(4)
0995NC20 LOCKWIRE
1491901-308-11
1491901-308-13
1.240
PNEUMATIC RESERVOIR
LIQUID SENSOR 30 IN³)
26512
14919C. 309



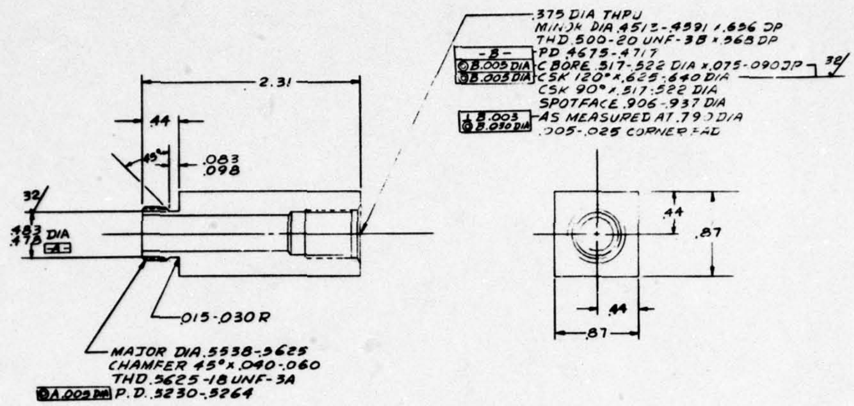
	A	B	C	D	E
-17	.299 .294	[illegible] .509	.406	.812	.630 .640
-21	.362 .357	.724 .714	.468	.937	.763 .753

1

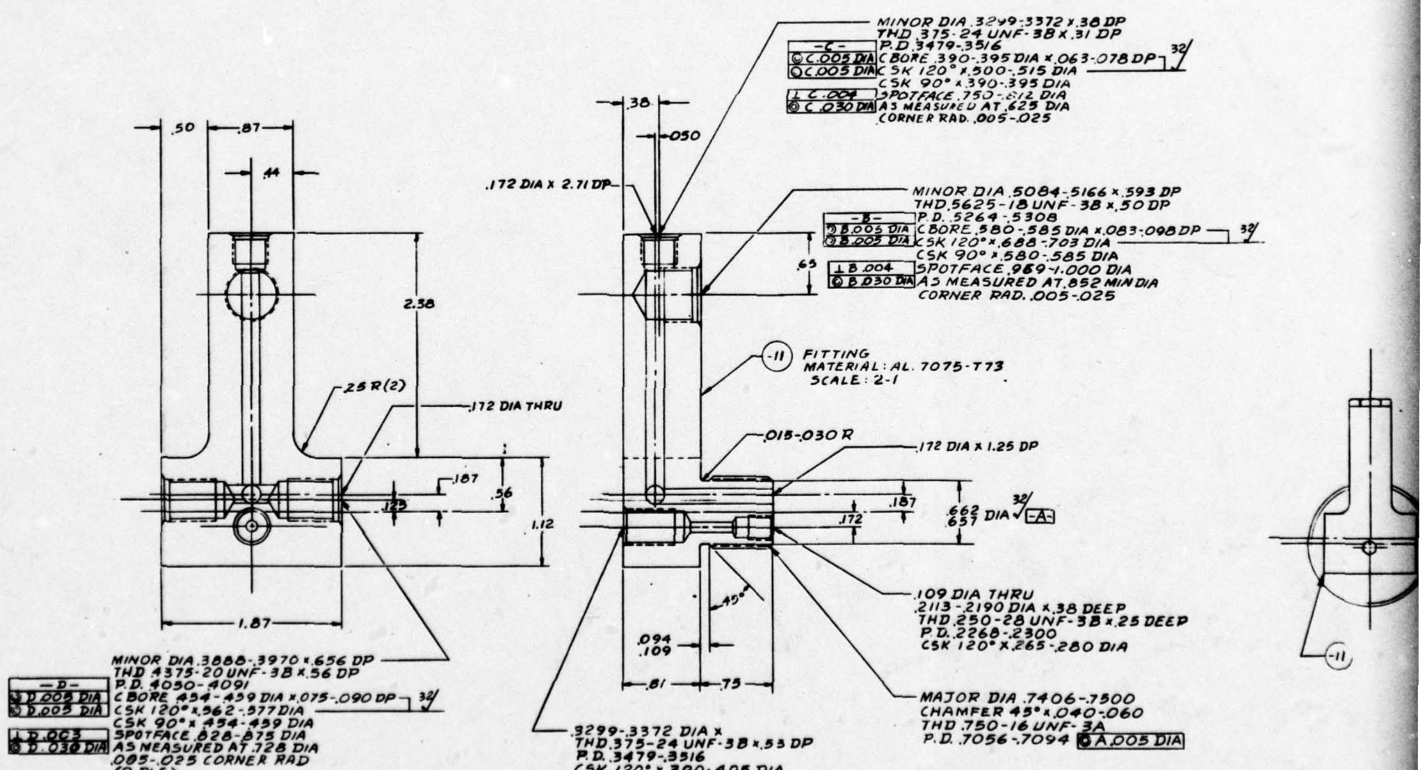
2



28SCH137-3 RAM AIR TURBINE ACCUMULATOR 50 IN³
MS28775-010
-15
7011FT-160PS
-11
-13
BOURNES 2001941301 LINER POTENTIOMETER
MINOR DIA .2113-.2190
THD .250-28 UNF-3B
P.D. .2268-.2300
CSK 120° x .265-.280 DIA (BOTH ENDS)
.500
.75
1.68
.191-.196 DIA
.312
.375
2.375
3.06
.25 R (TYP)
-13 ARM
MATERIAL: AL 7075-T73
SCALE: 1-1
.750
.312
10.750
.187
10.125
.090
.125R
.060 THD RELIEF
UNDERCUT TO .191-.201 DIA
.18
MAJOR DIA .2435-.2500
CHAMFER 45° x .020-.030
THD .250-28 UNF-3A
P.D. .2243-.2268
.030R
45°
.310
.309 DIA
.005
.010 R
A
.010 R POLISH FREE OF EDGE & TOOL MARKS
-11 PISTON
MATERIAL: CRES 303
SCALE: 4-1
ACCUMULATOR 50 IN³
SENSOR INSTALLATION A6
26512
1491901-310



(-13) UNION
MATERIAL: AL 7075-T73
SCALE: 2-1



(-11) FITTING
MATERIAL: AL 7075-T73
SCALE 2-1

1087-097(14)W

-.3372 x .38 DP
F-3B x .31 DP
DIA x .063-.078 DP
-.515 DIA
395 DIA
612 DIA
625 DIA
-.025

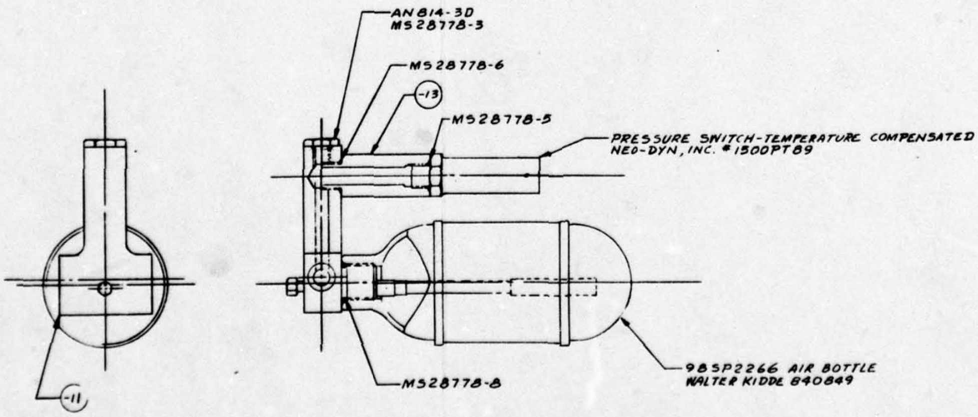
.5084-.5166 x .593 DP
-18 UNF-3B x .50 DP
-.5308
-.585 DIA x .083-.098 DP
588-.703 DIA
580-.585 DIA
.969-1.000 DIA
RED AT .852 MIN DIA
D. .005-.025

5 DP

A -A-

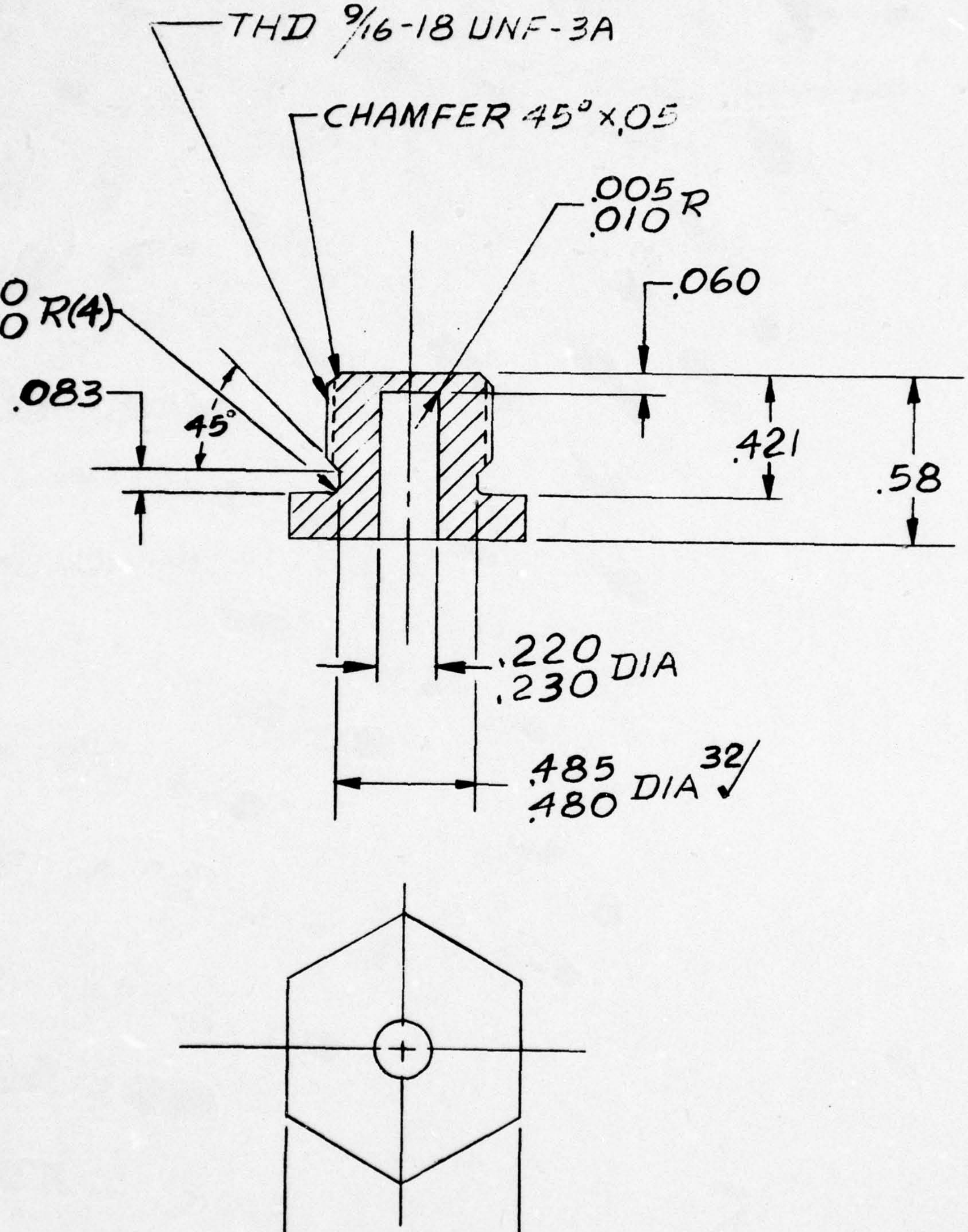
HRU
DIA x .38 DEEP
28 UNF-3B x .25 DEEP
-.2300
.265-.280 DIA

A .7406-.7500
45° x .040-.060
-16 UNF-3A
-.7094 A .005 DIA



PNEUMATIC RESERVOIR
REMOTE SENSING ASSY (15 IN³)

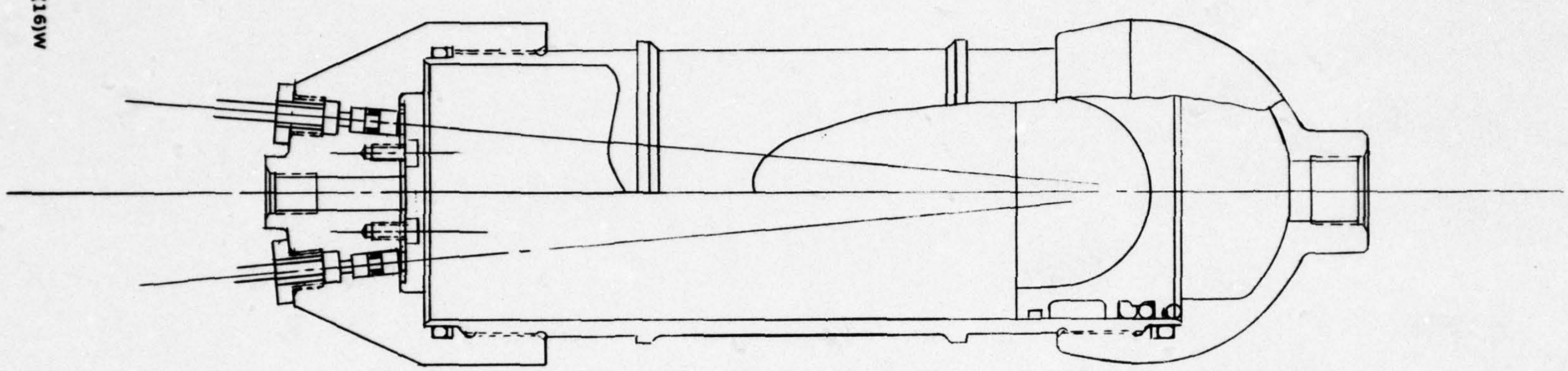
26512 | 1491901-311



MATERIAL: AL ALLY 7075-T6511
SCALE: 2-1

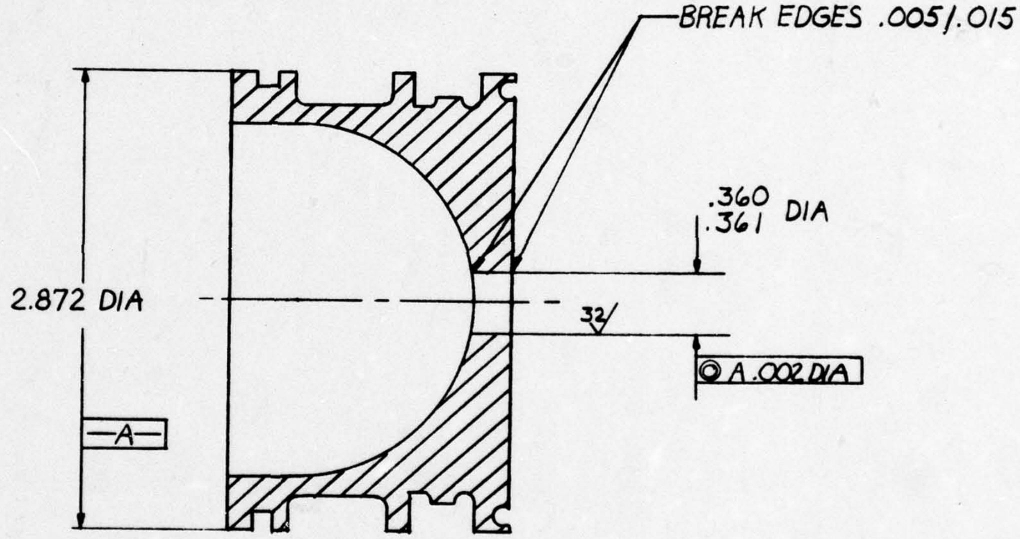
1087-097(15)W

FITTING, TEMPERATURE PROBE
1491-901-312



1087-097(16)W

ACCUMULATOR, PISTON DISPLACEMENT SENSOR, OPTICAL
1491-901-313



SECTION A-A

REF: SPRAGUE S-742 PISTON ASSY

1087-097(17)W

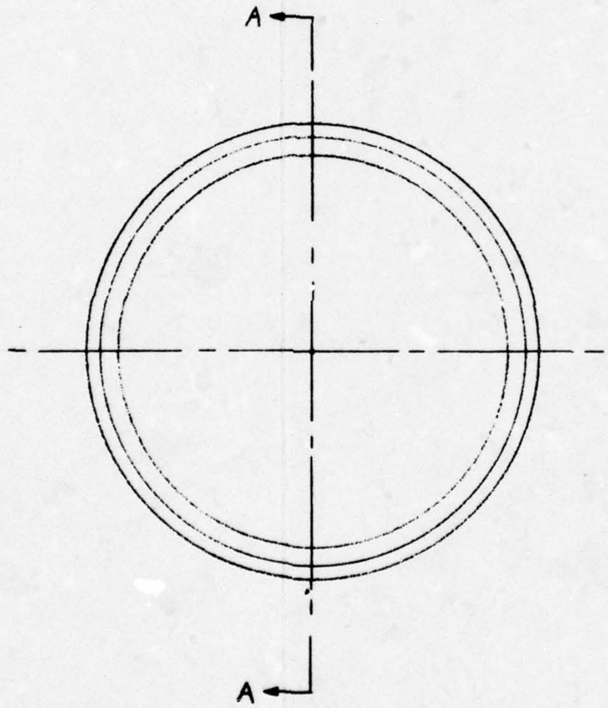
)

2

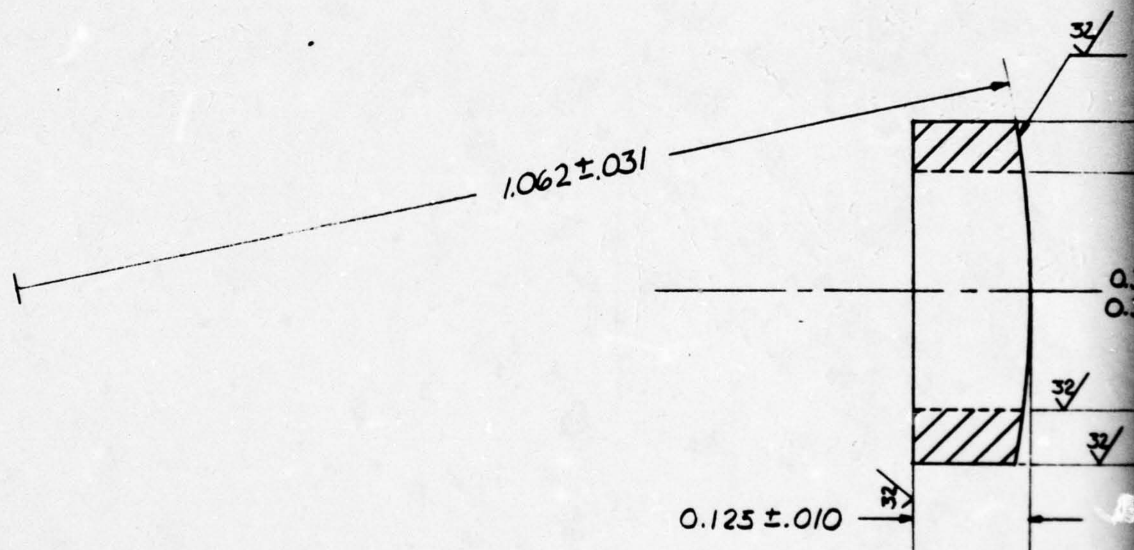
K EDGES .005/.015

DIA

.002 DIA



GRUMMAN AEROSPACE CORPORATION BETHPAGE, NEW YORK 11714		
SIZE B	CODE IDENT NO. 26512	PISTON, ACCUMULATOR MODIFICATION (50IN³) FOR ALC
SCALE 1:1	1491901-3/4	SHEET



SECTION A-A

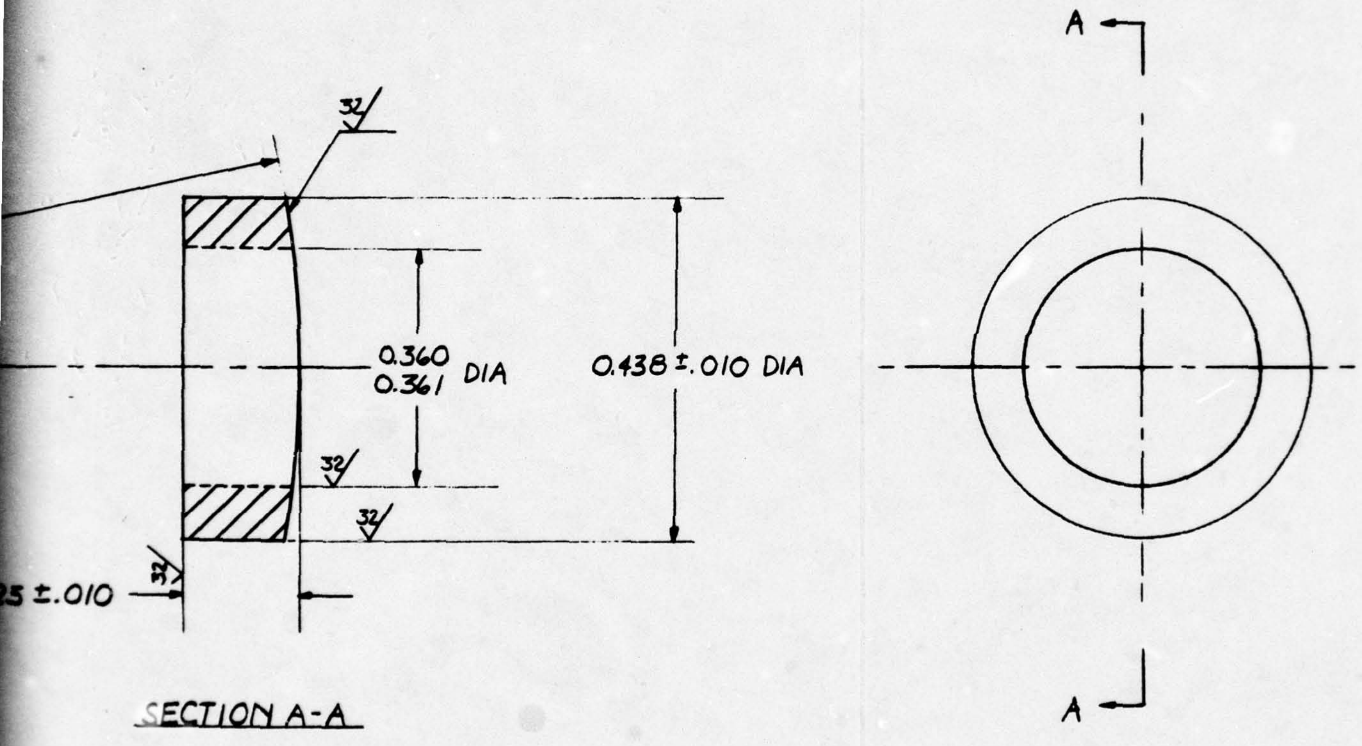
NOTES:

① MATERIAL CRES 303 OR EQUIVALENT
② BREAK ALL SHARP EDGES .005/.015"

1087-097(18)W

1

2



GRUMMAN AEROSPACE CORPORATION
BETHPAGE, NEW YORK 11714

SIZE	CODE IDENT NO.		
B	26512	WASHER, ACCUMULATOR MODIFICATION ($50 IN^3$) FOR ALC	
SCALE 1:6	1491901-315	SHEET 1	

APPENDIX H

SYSTEM AND COMPONENT WEIGHT ANALYSIS

HYCOS SYSTEM WEIGHT ANALYSIS

ITEM	DESCRIPTION	WEIGHT, LB	
		PROTOTYPE	PRODUCTION
1	DISPLAY PANEL	6.00	
2	RESERVOIR		
	PISTON DISPLACEMENT		
	POTENTIOMETER	0.08	
	BRACKETS, ADAPTORS & HOUSING	2.38 (EST)	
	TEMPERATURE TRANSDUCER	0.12	
3	FILTER DIFFERENTIAL PRESSURE		
	(a) INDICATORS	0.57	
	(b) MULTICATORS	0.36	
4	PRESSURE SWITCH, TEMPERATURE-COMPENSATED	0.25	
5	FLOW SENSORS		
	QUIESCENT	1.39	
	RUDDER ACTUATOR	0.57	
	PUMP CASE	0.52	
6	PRESSURE SWITCH, SYSTEM	0.09	
7	TEMPERATURE SWITCH		
	CASE DRAIN	0.13	
	FILTER MODULE (R.V.)		
	FLIGHT CONTROL BACKUP		
	MODULE, TEMPERATURE SWITCH	0.13	
8	POTENTIOMETER ROTARY		
	(a) RUDDER PEDALS	0.08	
	(b) RUDDER ACTUATOR	0.08	
9	TRANSDUCER, PRESSURE	0.18	
10	TRANSDUCER, TEMPERATURE	0.12	
11	WIRING, CLAMPS & CONNECTORS, BRACKETS	3 (EST)	
12	DETECTOR, LIQUID	0.03	
	TOTAL SYSTEM WEIGHT	16.08	

1087-091W

APPENDIX I

PANEL WIRING DIAGRAM

AND

PARTS LIST

1087-096(1)W

INTEGRATED CIRCUITS

1	8748	µprocessor	INTEL	125
5	8703	A/D CONVERTER	TELEDYNE	115.
1	5101	CMOS MEMORY	INTEL	17
9	DS3614	LAMP DRIVERS	NATIONAL	45.
1	54LS04	HEX INVERTER		2.
3	54LS74	DUAL 'D' FF		6
1	54LS95	QUAD SR		4
2	54LS125	QUAD BUS BUFFER		4.
5	54LS138	3 TO 8 LINE DECODER		25
2	54143	COUNTER LATCH DECODER		30
2	54LS367	HEX BUS DRIVER		4

SEMICONDUCTORS

7	2N2222	NPN TRANSISTOR
1	2N2905	PNP TRANSISTOR
3	1N3612	RECTIFIER DIODE
22	1N4148	SWITCHING DIODE

COMPONENTS

1	M1-050-030-272	THERMOSTAT	TI	20
1	M1-104-084-172	THERMOSTAT	TI	20
2	HK5035-60.7OHM	HEATING STRIP	MINCO PRODUCTS	42.
1	MP060	CRYSTAL	BAILEY	6.
4	432DM2-5	RELAY	TELEDYNE	145.
1	15E35CT	TRANSFORMER	ABBOT	30.
4	XGCR1.0ST	NICAD BATTERY 1AM	GE	25
8	XGCF100ST	NICAD BATTERY 100MAH	GE	35.
2	MS27717-272	DPDT MOM. SWITCH CENTER OFF		15
1	MS17322-5	ELAPSED TIME METER		50.
7	68 pf	CAPACITOR		20
7	270pf	CAPACITOR		20
28	.1mf	CAPACITOR		50
1	.56mf	CAP		5
5	10mf	CAPACITOR		25
80	1/4w 5%	RESISTORS		25
1	51Ω 1w 5%	RESISTOR		1
[illegible]	[illegible]	[illegible]	BOURNS MFT	10

1	MS 17322-5 ELAPSED TIME METER		
7	68 pf CAPACITOR		20
7	270 pf CAPACITOR		20
28	.1 mf CAPACITOR		50
1	.56 mf CAP		5
5	10 mf CAPACITOR		25
80	1/4w 5% RESISTORS		25
1	51Ω 1w 5% RESISTOR		1
2	7104D-400-103 QUAD 10K POTS IN 16 PIN DIPS BOURNS MFT		10
1	M81511/41 FA01 P1 CONNECTOR		20.
1	M81511/41 FD01 P1 CONNECTOR		25
1	M81511/41 FB01 P1 CONNECTOR		25
4	GC 825 BU1 PC CONNECTOR	TRANSITRON	140.
4	GC 825 BN2 PC CONNECTOR	TRANSITRON	120.
4	PE 10079 CIRCUIT BOARDS	AUGAT	325
53	BEPHBA05 LAMP ASSEMBLIES	SHELLY	150

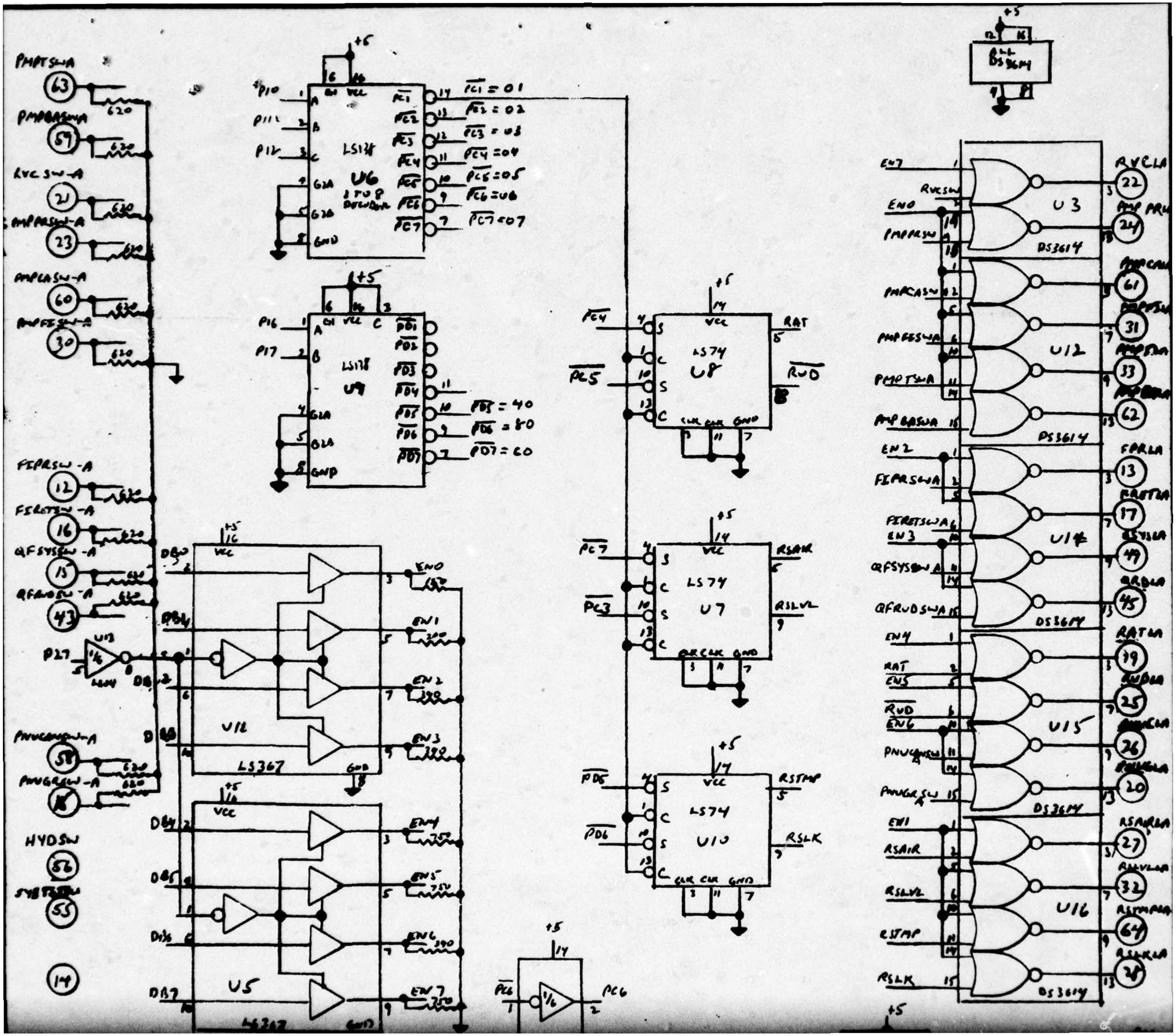
\$1,721

REV A DATE 11/21/78

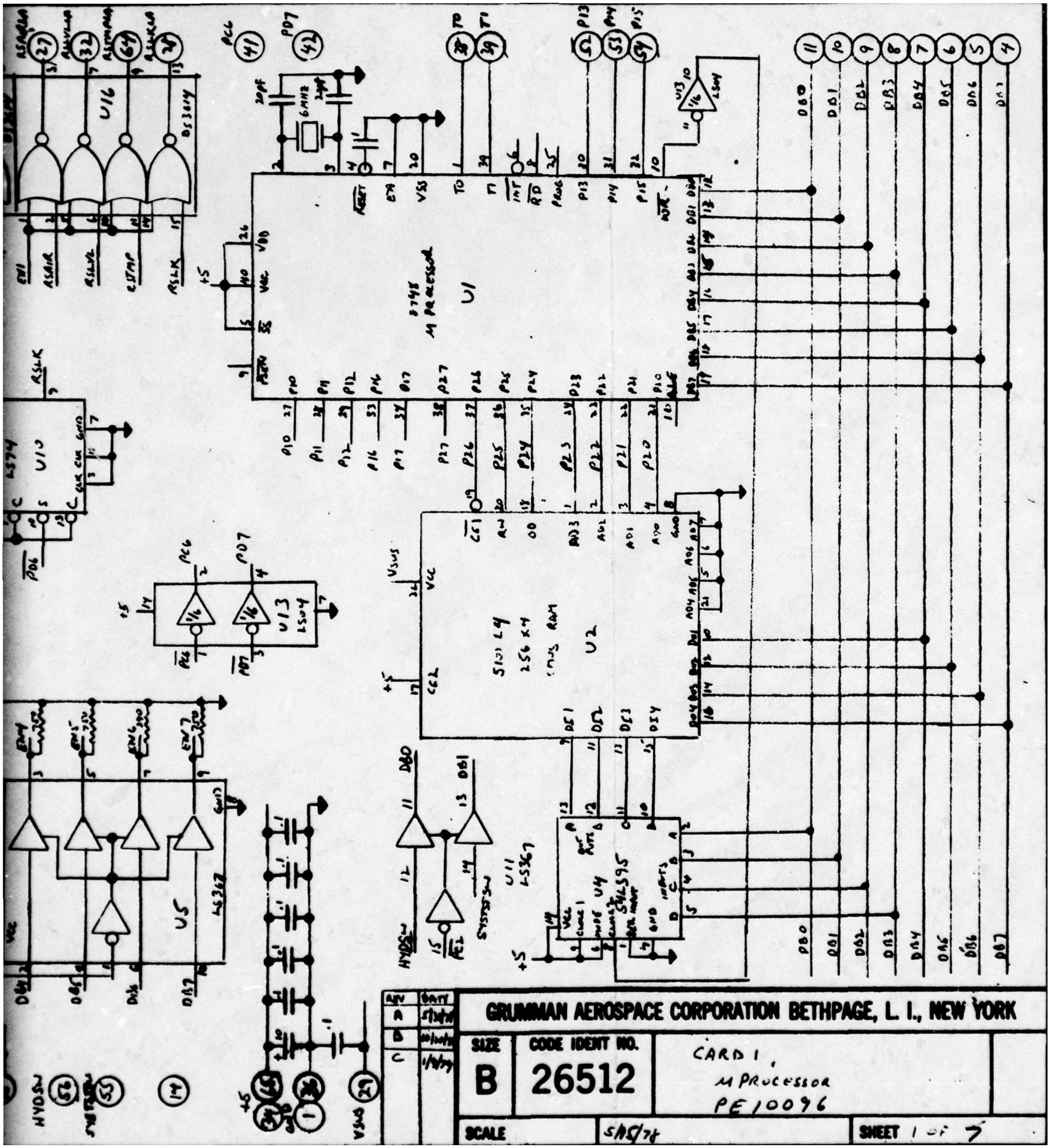
GRUMMAN AEROSPACE CORPORATION BETHPAGE, L. I., NEW YORK

SIZE	CODE IDENT NO.	
B	26512	ELECTRONIC PARTS HYCOS

SCALE 6/2/78 SHEET



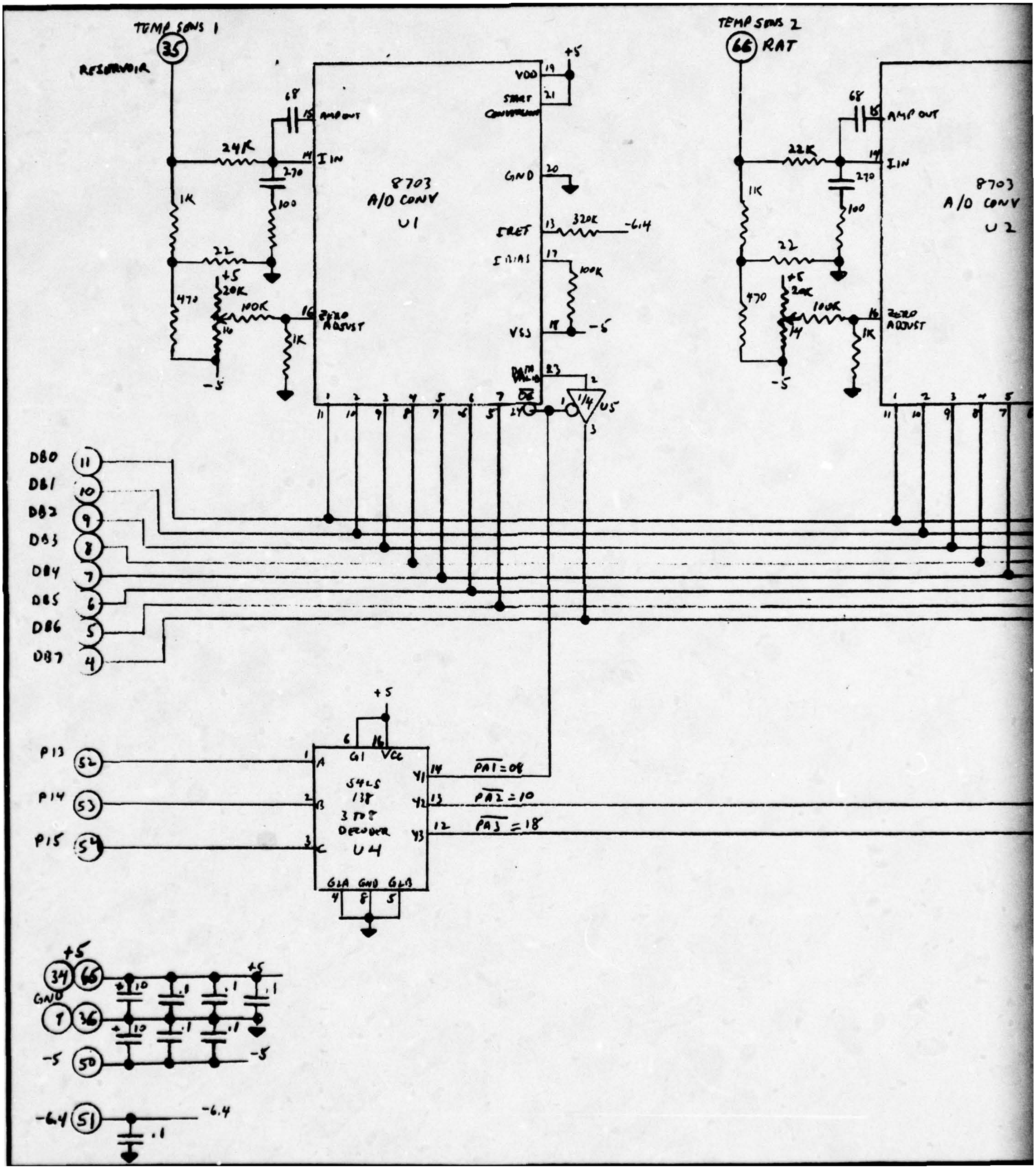
U6
LS138
U9
LS74
U8
U7
U10
U3
U12
U14
U15
U16
DS3614
LS367
U5
HYDSW



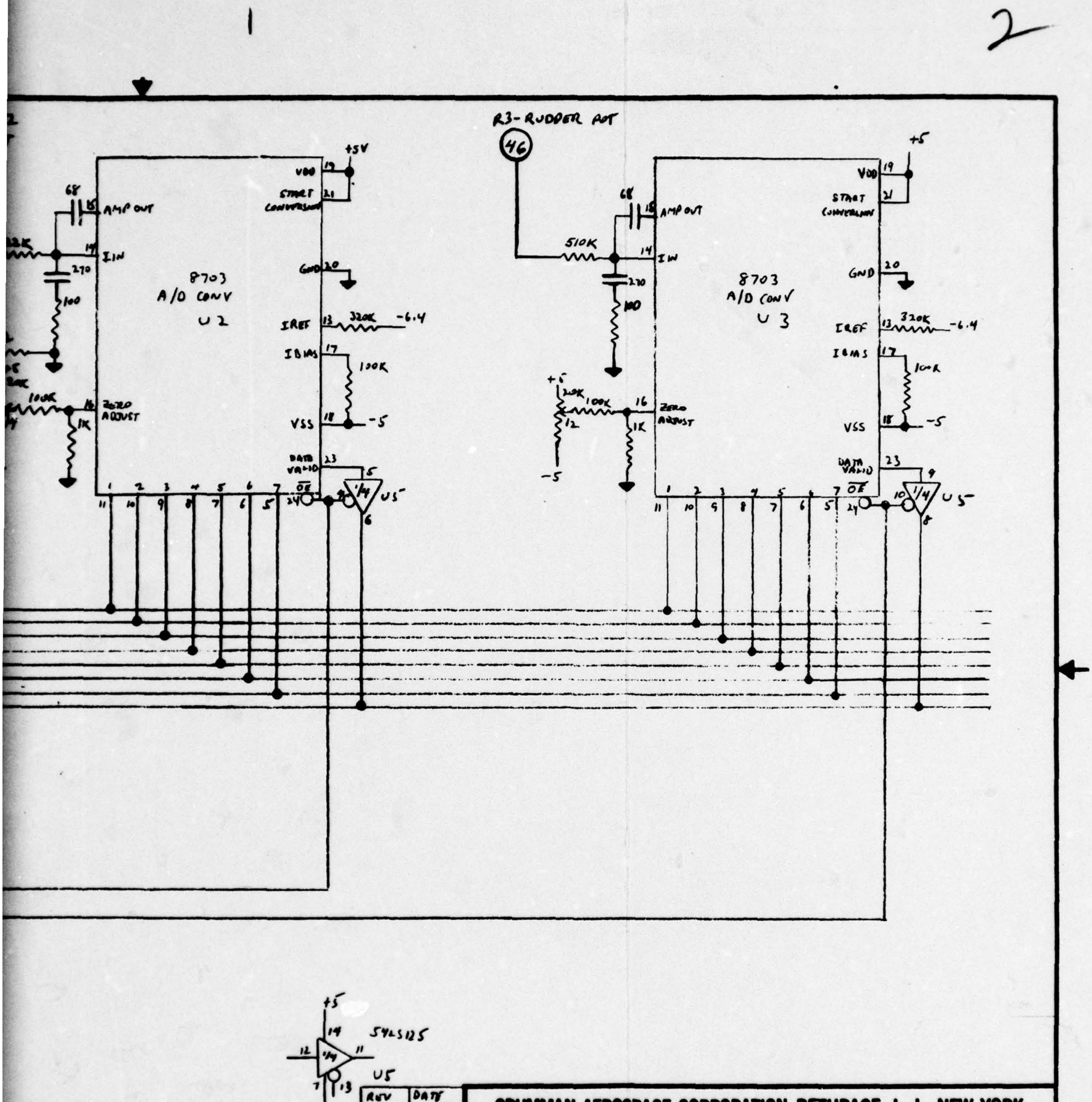
GRUMMAN AEROSPACE CORPORATION BETHPAGE, L. I., NEW YORK

SIZE	CODE IDENT NO.	
B	26512	CARD 1, M PROCESSOR PE10096

SCALE 5/15/78 SHEET 1 OF 7



TEMP SENS 1
35
RESERVOIR
8703
A/D CONV
U1
VDD
START CONVERSION
AMP OUT
I IN
GND
IREF
IBIAS
VSS
ZERO ADJUST
DATA VALID
24K
270
100
1K
22
470
20K
100K
68
320K
-6.4
-5
+5
1/4 U5
TEMP SENS 2
66 RAT
22K
A/D CONV
U2
DB0
DB1
DB2
DB3
DB4
DB5
DB6
DB7
P13
P14
P15
54LS
138
3 TO 8
DECODER
U4
G1
VCC
G2A
GND
G2B
PA1 = 08
PA2 = 10
PA3 = 18
GND

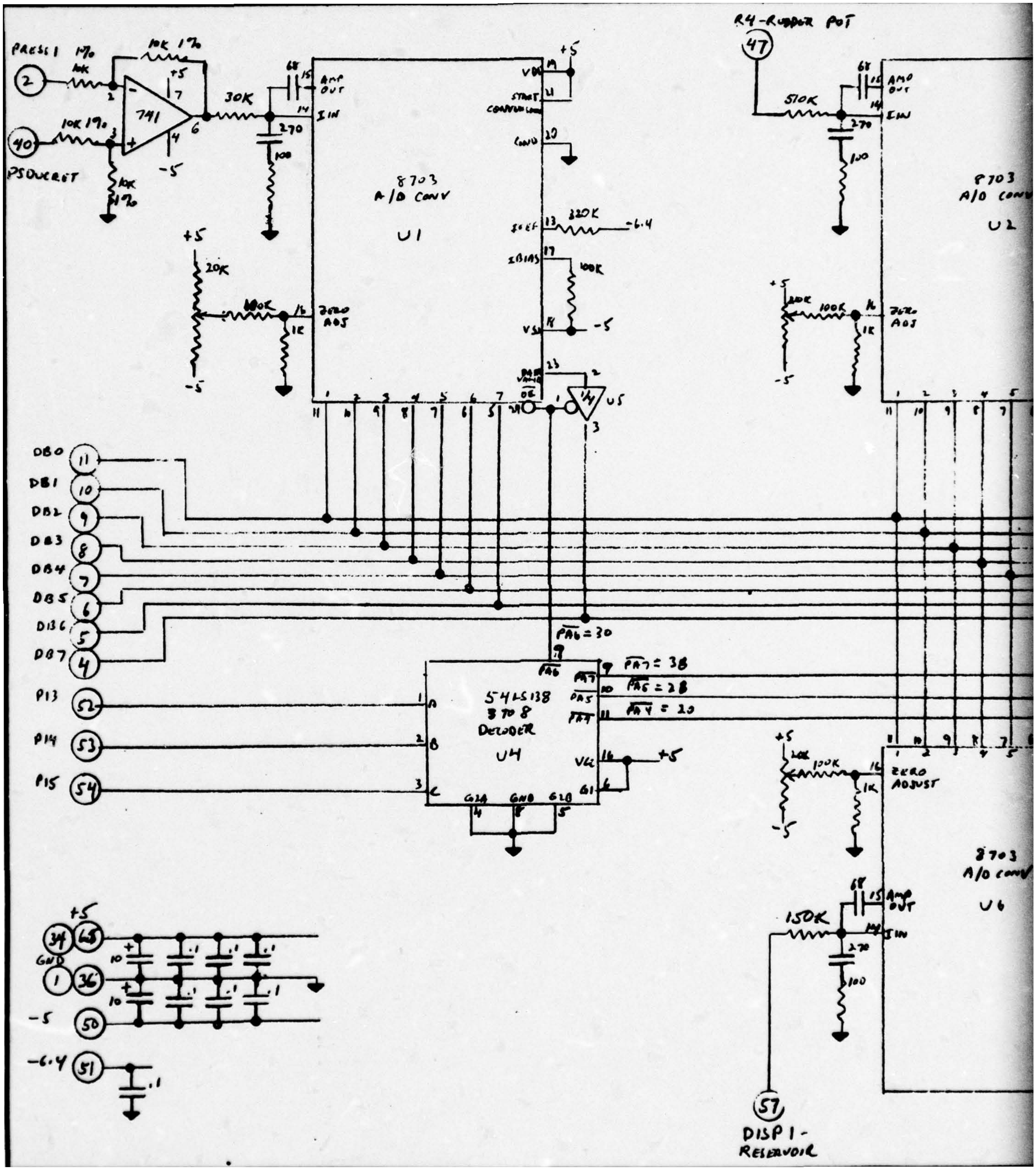


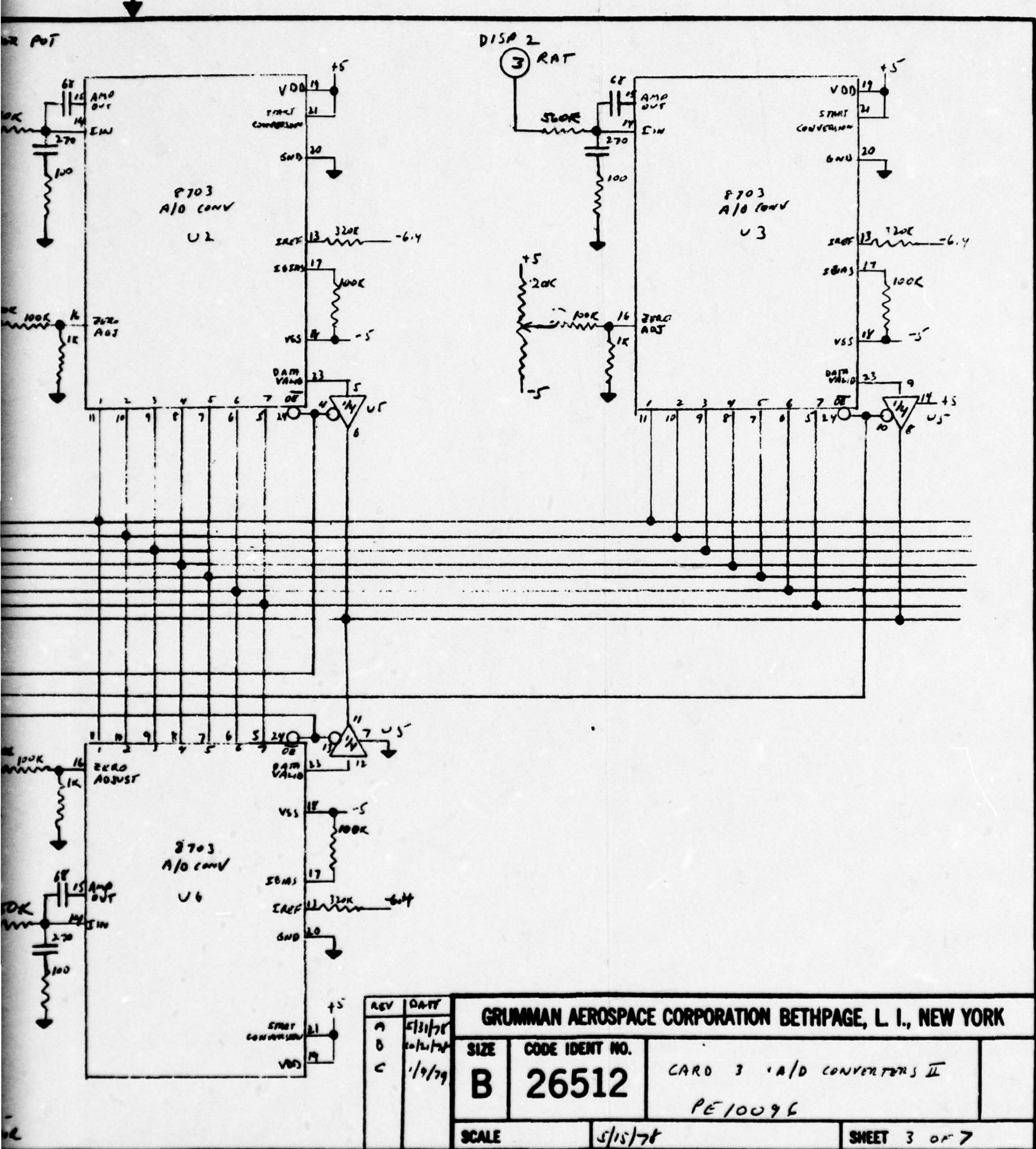
REV	DATE
A	5/30/78
B	10/20/78
C	1/9/79

GRUMMAN AEROSPACE CORPORATION BETHPAGE, L. I., NEW YORK

SIZE B | CODE IDENT NO. 26512 | CARD 2 - A/D CONVERTERS | PE10096

SCALE | 5/15/78 | SHEET 2 OF 7

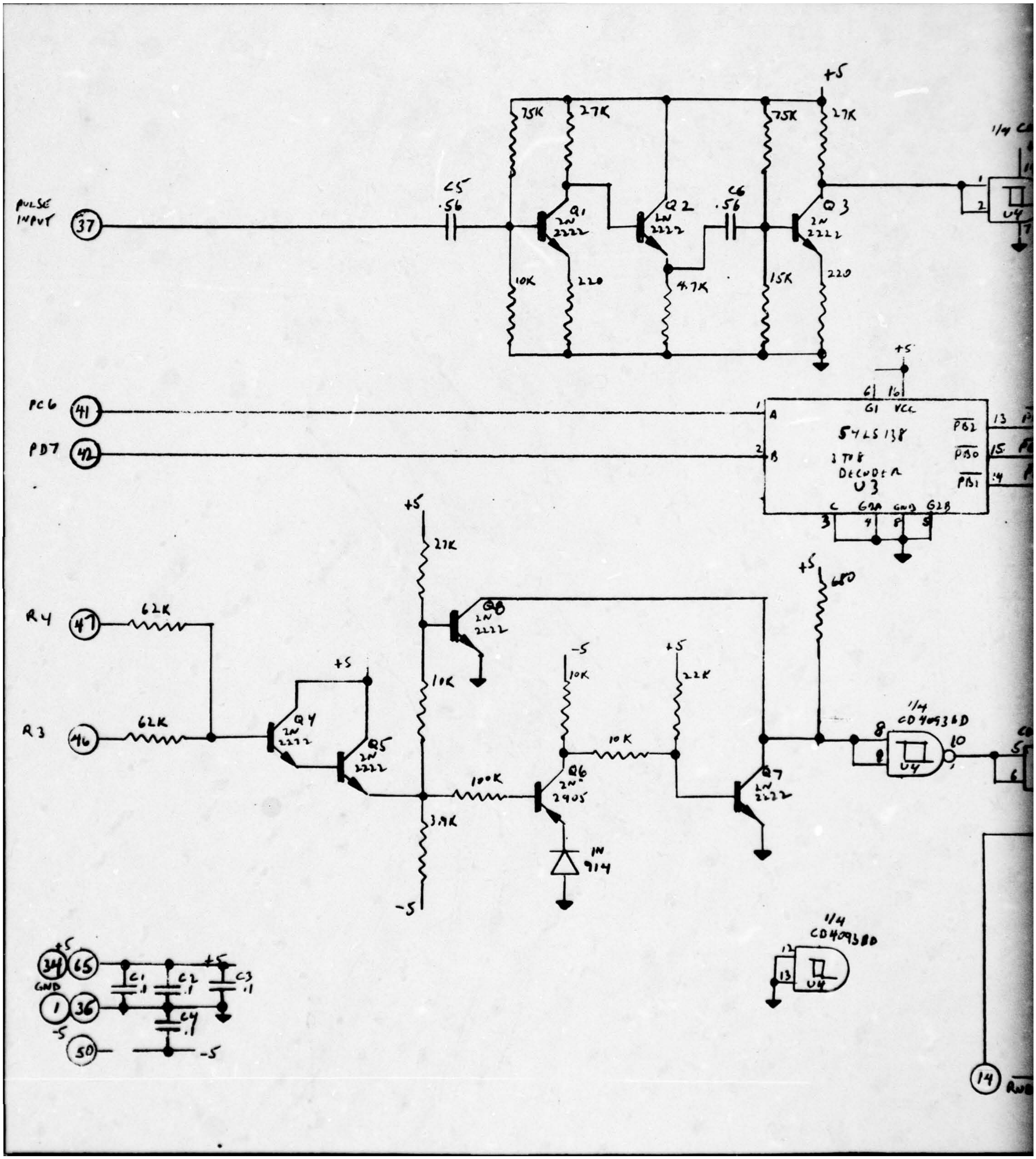

R4-RUDDER POT
PRESS 1
PSDUCRET
741
30K
8703
A/D CONV
U1
U2
U6
U4
U5
54LS138
3 TO 8
DECODER
ZERO ADJ
ZERO ADJUST
AMP OUT
DB0
DB1
DB2
DB3
DB4
DB5
DB6
DB7
P13
P14
P15
510K
150K
320K
100K
20K
DISP 1-
RESERVOIR

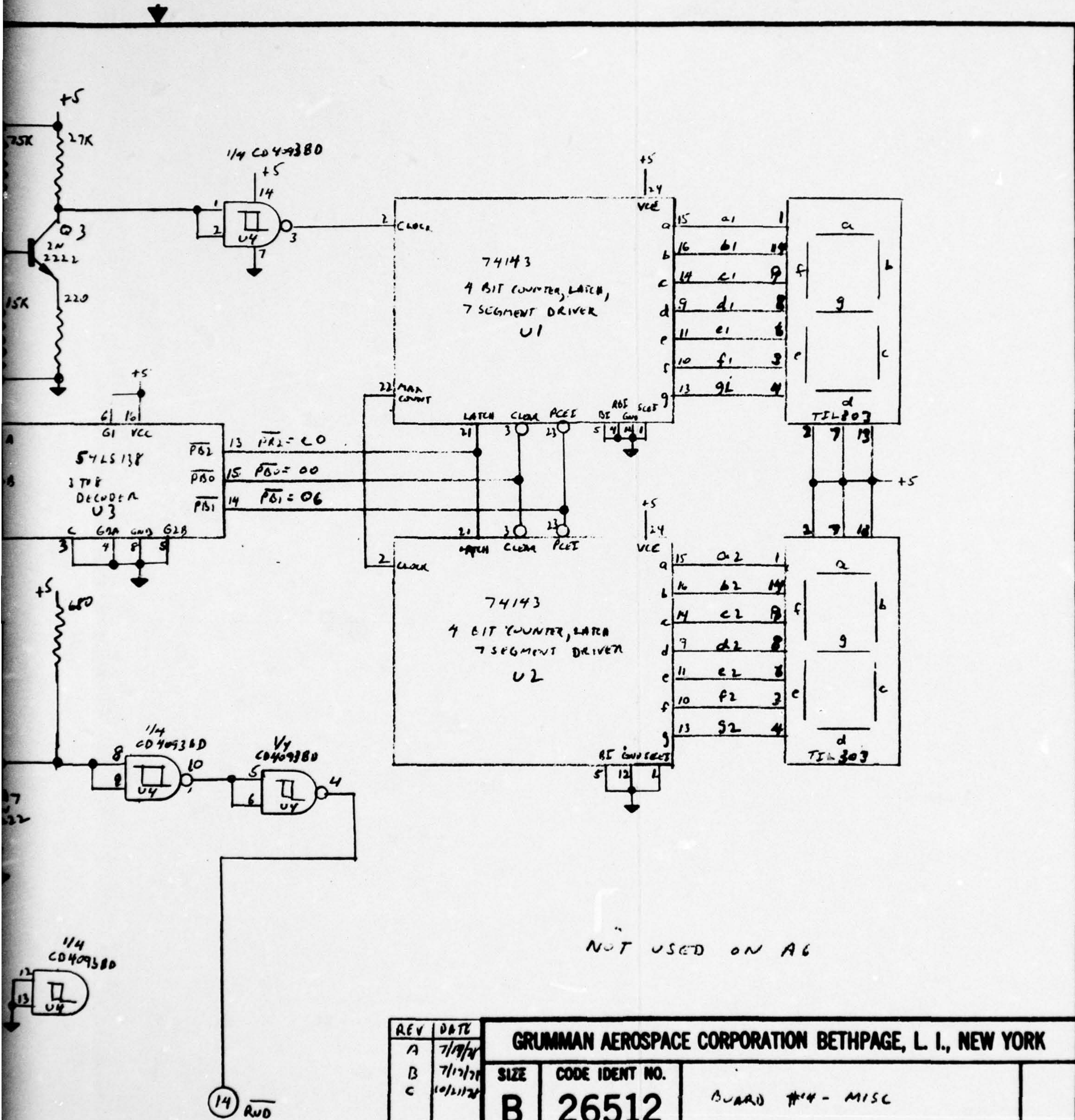


REV	DATE
A	5/31/78
B	10/21/78
C	1/9/79

GRUMMAN AEROSPACE CORPORATION BETHPAGE, L. I., NEW YORK

SIZE	CODE IDENT NO.	
B	26512	CARD 3 A/D CONVERTERS II PE1009C
SCALE	5/15/78	SHEET 3 OF 7


PULSE INPUT
37
C5 .56
75K
27K
10K
220
Q1 2N 2222
Q2 2N 2222
4.7K
C6 .56
Q3 2N 2222
15K
+5
1/4 CD
U4
PC6
41
PD7
42
54LS138
3 TO 8 DECODER
U3
G1
VCC
PB2
PB0
PB1
R4
47
R3
46
62K
Q4 2N 2222
Q5 2N 2222
Q8 2N 2222
100K
3.9K
Q6 2N 2905
1N 914
22K
Q7 2N 2222
680
1/4 CD4093BD
-5
34
65
GND
1
36
50
C1 .1
C2 .1
C3 .1
C4 .1
14

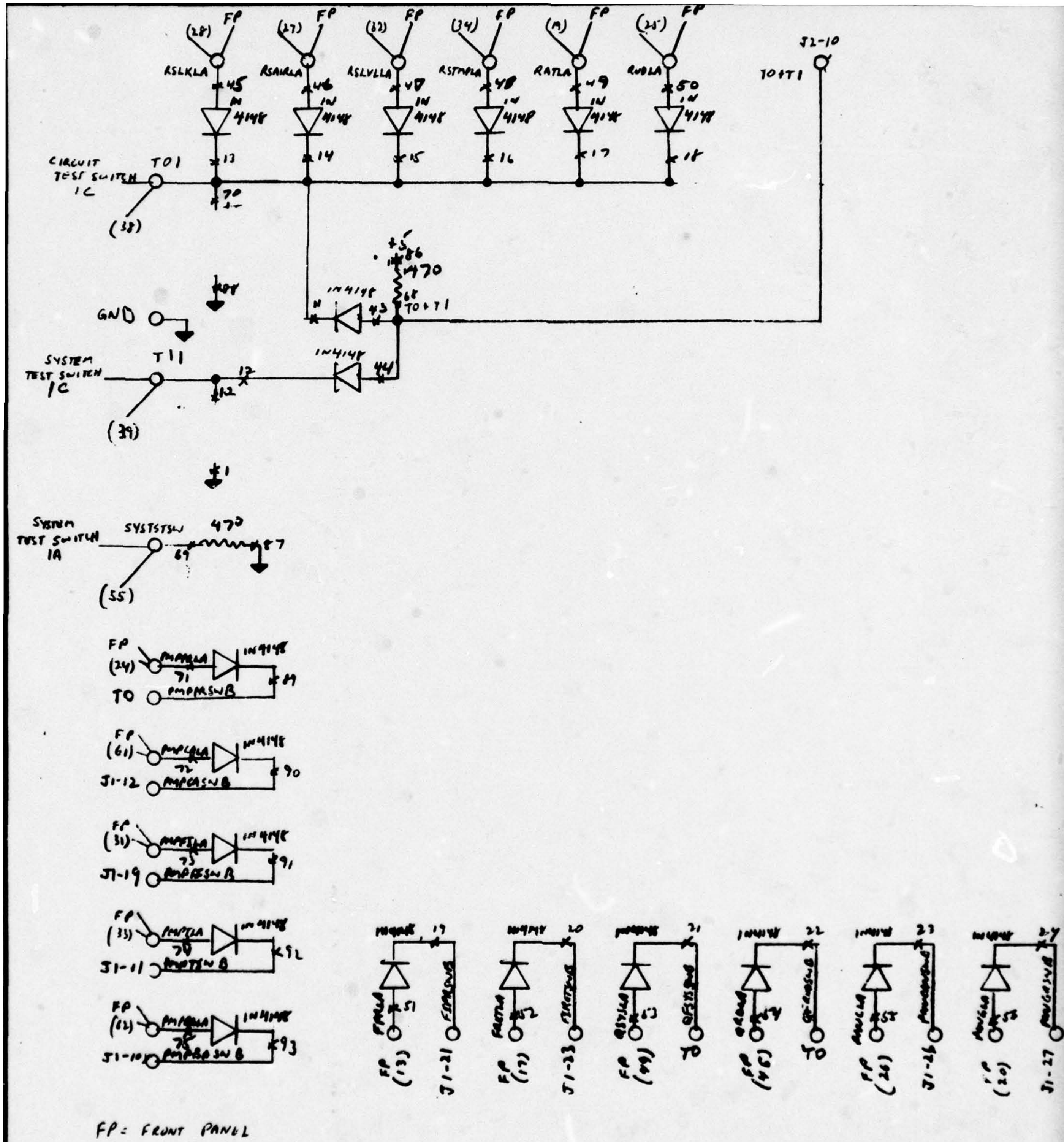


REV	DATE
A	7/19/78
B	7/17/78
C	10/21/78

GRUMMAN AEROSPACE CORPORATION BETHPAGE, L. I., NEW YORK

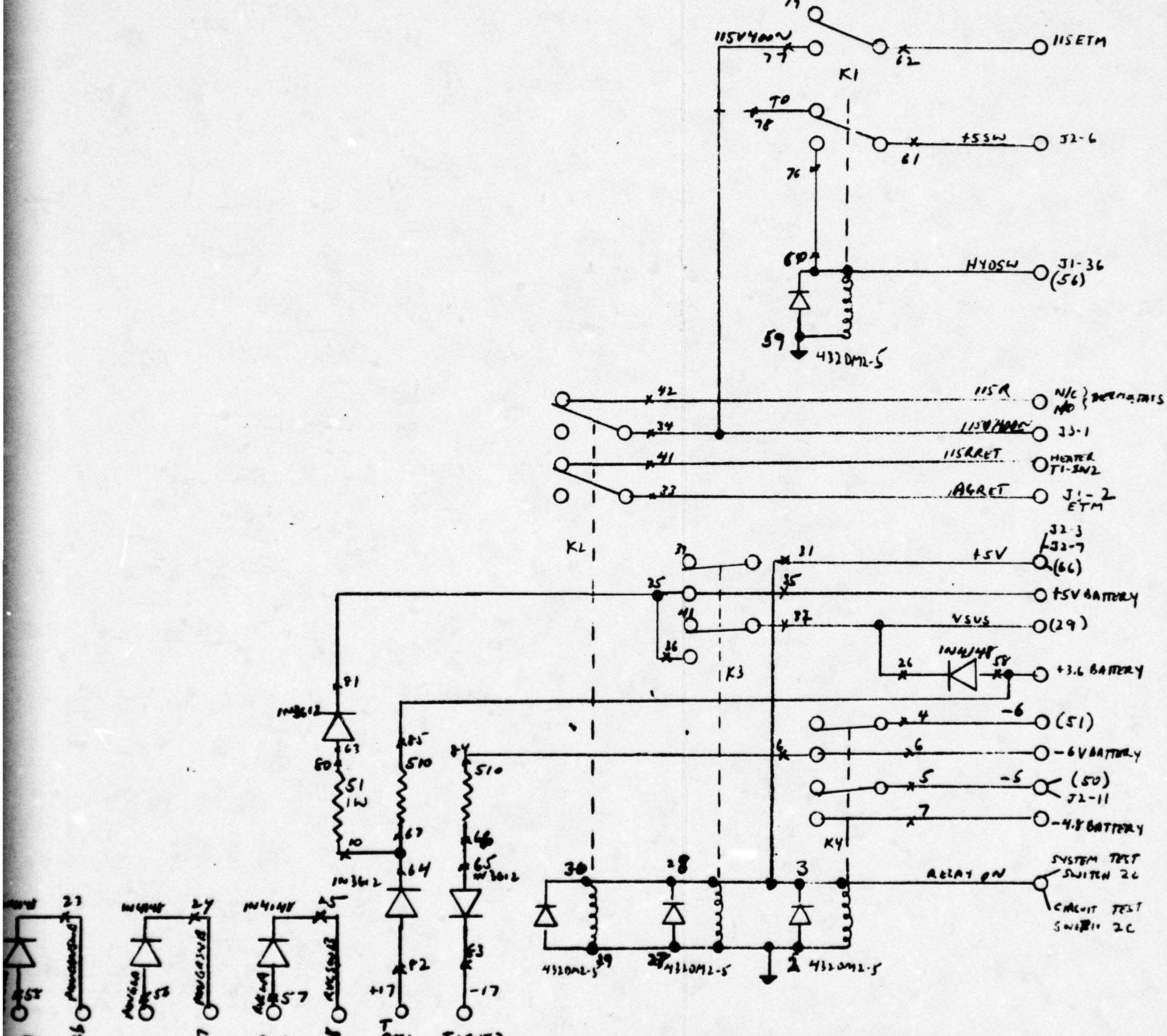
SIZE B | CODE IDENT NO. 26512 | BOARD #4 - MISC PE 10096

SCALE | SHEET 4 OF 7



FP = FRONT PANEL

( ) = PIN # ON BUS

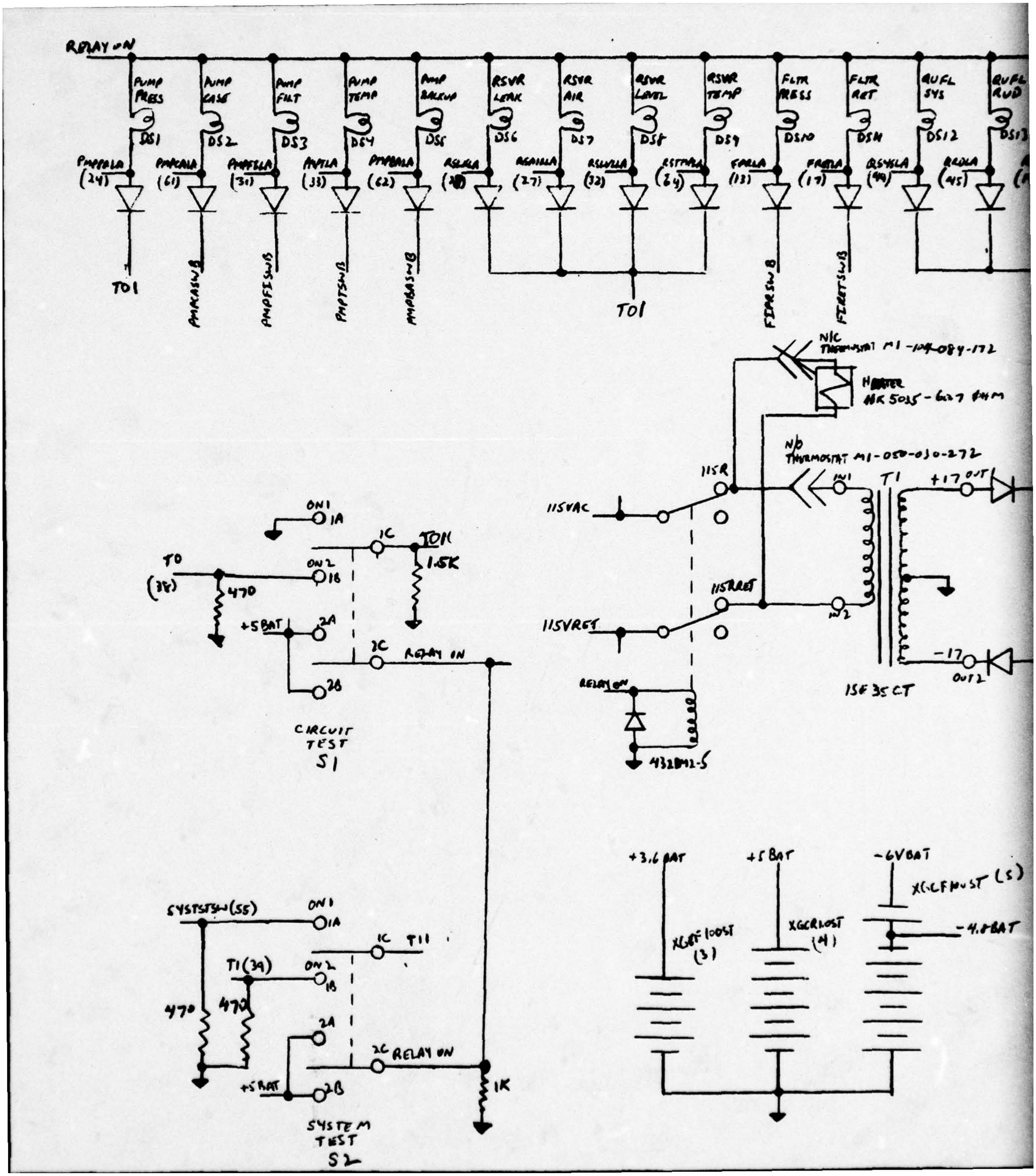


GRUMMAN AEROSPACE CORPORATION BETHPAGE, L. I., NEW YORK

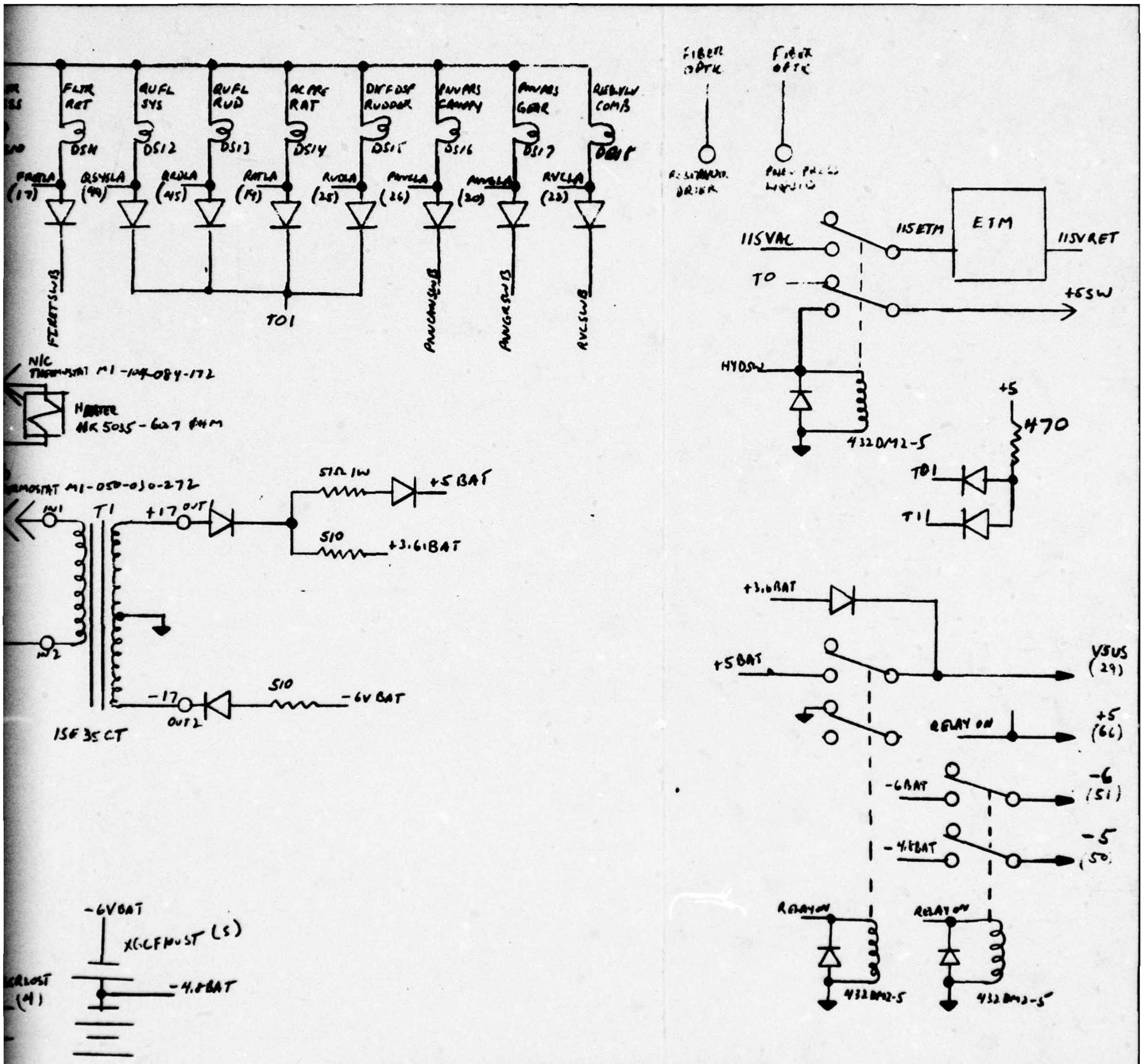
REV	DATE
A	5/17/78
B	10/21/78

SIZE	CODE IDENT NO.	
B	26512	SPECIAL BOARD -A5 PE10096

SCALE 5/15/78 SHEET 5 OF 7



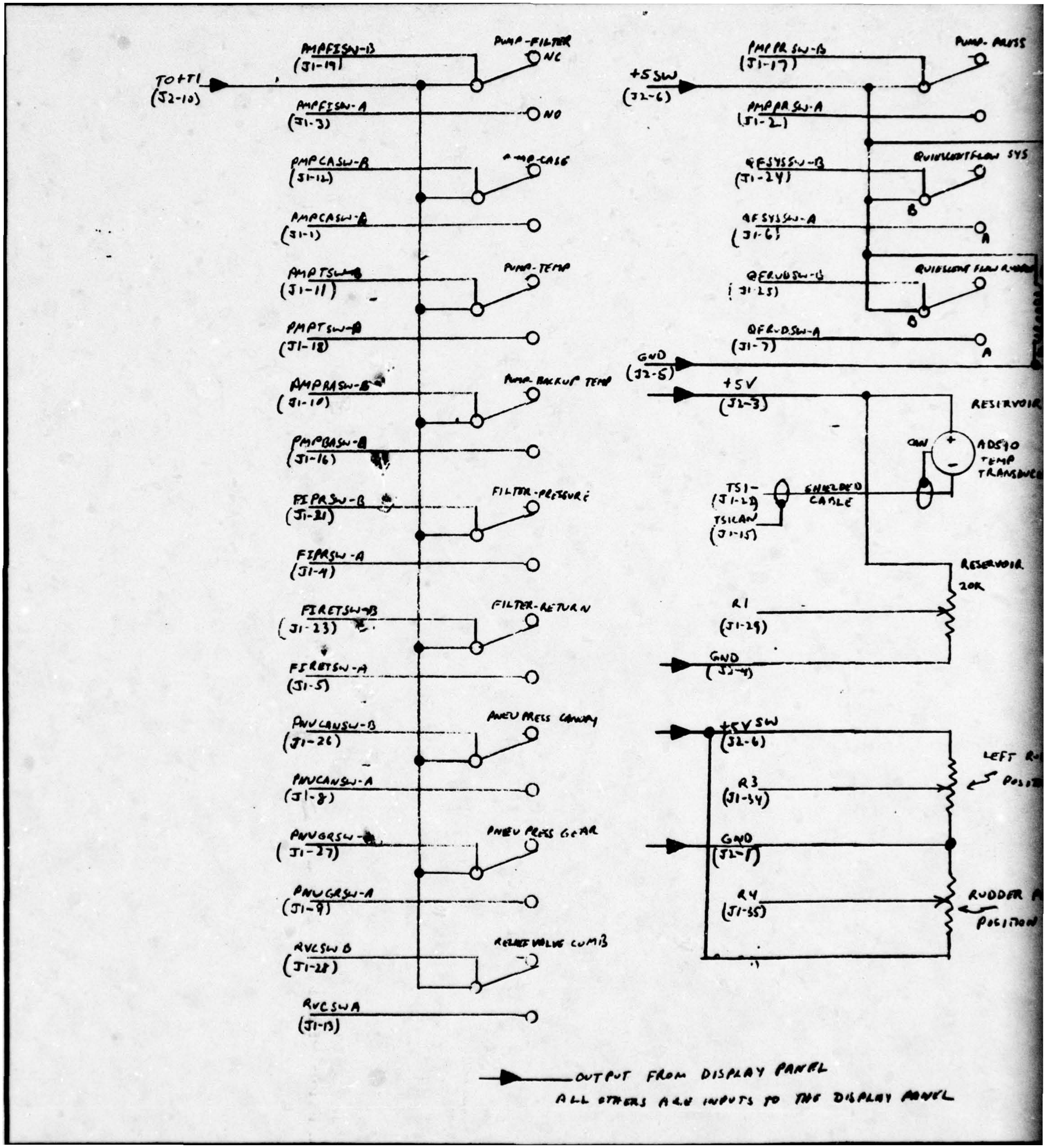
RELAY ON
PUMP PRESS
PUMP CASE
PUMP FILT
PUMP TEMP
PUMP BACKUP
RSVR LEAK
RSVR AIR
RSVR LEVEL
RSVR TEMP
FLTR PRESS
FLTR RET
QUFL SYS
QUFL RUD
DS1
DS2
DS3
DS4
DS5
DS6
DS7
DS8
DS9
DS10
DS11
DS12
DS13
TO1
FLTRSWB
FLTRTSWB
N/C THERMOSTAT M1-104-084-172
HEATER
N/O THERMOSTAT M1-050-030-272
115R
115VAC
115VRET
115RRET
IN1
IN2
T1
+17 OUT
-17 OUT2
15F35CT
RELAY ON
432DM2-5
ON1
1A
1C
ON2
1B
TO
(38)
470
1.5K
+5BAT
2A
2C
RELAY ON
2B
CIRCUIT TEST
S1
+3.6 BAT
+5 BAT
-6VBAT
(3)
(4)
(5)
-4.8BAT
SYSTSTSW(55)
T1(34)
T11
470
1K
SYSTEM TEST
S2



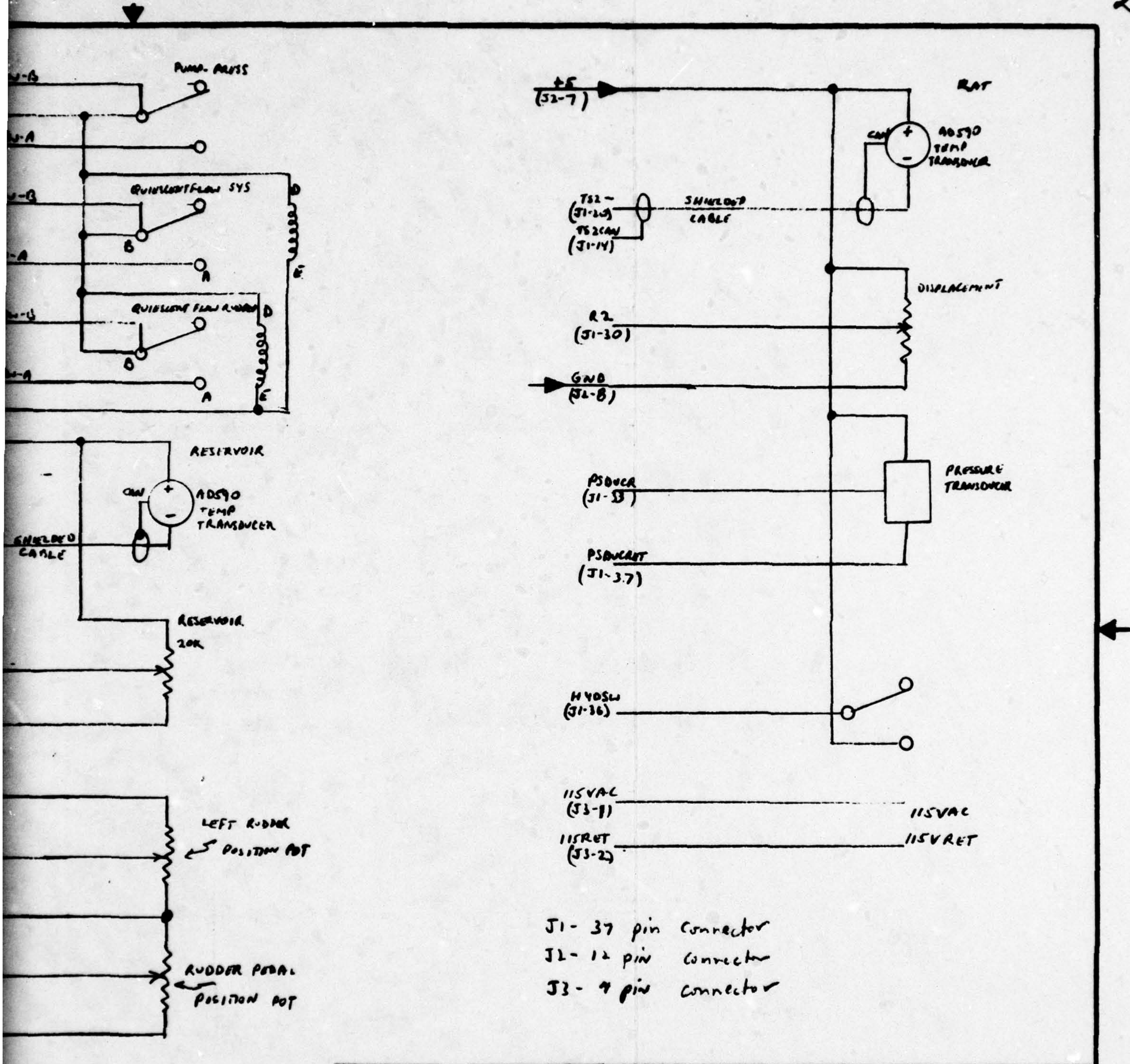
DATE	REV
5/17/78	A
10/24/78	B

GRUMMAN AEROSPACE CORPORATION BETHPAGE, L. I., NEW YORK

SIZE	CODE IDENT NO.	
B	26512	FRONT PANEL, POWER SUPPLY, MISC. CIRCUITS CARD (A5) PE 10046
SCALE	5/15/78	SHEET 6 OF 7



TO+T1 (J2-10)
PMPFISW-B (J1-19)
PUMP-FILTER
NC
PMPFISW-A (J1-3)
NO
PMPCASW-B (J1-12)
PMPCASW-A (J1-1)
PUMP-TEMP
PMPTSW-B (J1-11)
PMPTSW-A (J1-18)
PMPBASW-B (J1-10)
PMPBASW-A (J1-16)
FILTER-PRESSURE
FIPRSW-B (J1-21)
FIPRSW-A (J1-4)
FILTER-RETURN
FIRETSW-B (J1-23)
FIRETSW-A (J1-5)
PNVCANSW-B (J1-26)
PNVCANSW-A (J1-8)
PNEU PRESS GEAR
PNVGRSW-B (J1-27)
PNVGRSW-A (J1-9)
RVCSW B (J1-28)
RVCSW A (J1-13)
+5 SW (J2-6)
PMPPR SW-B (J1-17)
PMPPR SW-A (J1-2)
QFSYSSW-B (J1-24)
QFSYSSW-A (J1-6)
QFRUDSW-B (J1-25)
QFRUDSW-A (J1-7)
B
A
GND (J2-5)
+5V (J2-3)
AD590
TEMP
CAN
SHIELDED CABLE
TS1- (J1-29)
TS1CAN (J1-15)
RESERVOIR
20K
R1 (J1-29)
GND (J2-4)
+5V SW (J2-6)
R3 (J1-34)
GND (J2-7)
R4 (J1-35)
OUTPUT FROM DISPLAY PANEL
ALL OTHERS ARE INPUTS TO THE DISPLAY PANEL



REV	DATE
A	7/20/78
B	1/23/79

GRUMMAN AEROSPACE CORPORATION BETHPAGE, L. I., NEW YORK

SIZE	CODE IDENT NO.	
B	26512	I/O PE 10096
SCALE	5/17/78	SHEET 7 OF 7

APPENDIX J

MICROPROCESSOR PROGRAM

1087-093W(1)

```
ASM48 HYCOS.SRC TITLE ('HYCOS') PRINT (:LP:)


ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0            PAGE    1
HYCOS

 LOC  OBJ         SEQ        SOURCE STATEMENT

 0000               1               ORG 0H
 0000 E5            2               SEL MB0         ;INITIAL CONDITION
 0001 C5            3               SEL RB0         ;MEMORY AND RGISTER BANK 0
                    4         ;EXECUTIVE ROUTINE
                    5         ;ROUTINE TO BE FOLLOWED EVERY TIME POWER IS
                    6         ;APPLIED .WE CHECK TO SEE IF CIRCUIT TEST
                    7         ;SWITCH IS ON2(T0),IF SYSTEM TEST SWITCH IS
                    8         ;ON1(CHECK BIT 1 ON BUS),IF SYSTEM TEST IS ON2
                    9         ;(T1). WE DEFAULT TO CIRCUIT TEST ON1
 0002 80           10 START:  MOVX A,@R0            ;DISABLE BUS.
 0003 2310         11         MOV A,#10H            ;DISABLE MEMORY
 0005 3A           12         OUTL P2,A             ;DISABLE MEMORY
 0006 27           13         CLR A                 ;SET INITIAL CONDITIONS
 0007 17           14         INC A                 ;RESET FF
 0008 39           15         OUTL P1,A             ;  "   "
 0009 3614         16         JT0 SQNCE             ;IF T0 DO SEQUENCE ROUTINE
 000B 5644         17         JT1 AIR               ;IF T1 DO AIR ROUTINE
 000D 17           18         INC A                 ;CHECK STATE
 000E 39           19         OUTL P1,A             ;    OF SYSTEM
 000F 08           20         INS A,BUS             ;        TEST SWITCH
 0010 3223         21         JB1 RMLD              ;IF SWITCH IS ON1 DO RAM LOAD
 0012 0402         22         JMP START
                   23
                   24         ;SEQUENCE SUBROUTINE
                   25         ;THIS SUBROUTINE WILL LIGHT ALL THE LAMPS BY BLOCKS,
                   26         ;FIRST THE PUMPS (5 LAMPS),THEN RESERVOIR (4 LAMPS),
                   27         ;ETC.LAMPS WILL STAY ON FOR 1/2 SECOND THEN SEQUENCE
                   28         ;TO NEXT BLOCK
                   29
                   30
 0014 2380         31 SQNCE:        MOV A,#080H     ;OUTPUT TO GET P27 AND TO
 0016 3A           32               OUTL P2,A       ;    DISABLE MEMORY FROM BUS
 0017 2301         33               MOV A,#01H      ;START BUS AT BEGINNING
 0019 02           34 TSTUT:        OUTL BUS,A      ;OUTPUT TO BUS TO LIGHT LAMPS
 001A BA32         35               MOV R2,#32H     ;PRELOAD R2 FOR 1/2 SECOND TIMING
 001C AB           36               MOV R3,A        ;SAVE POSITION OF LAMPS IN R3
 001D 343B         37               CALL MS10       ;GET 1/2 SECOND TIMING SUBROUTINE
 001F FB           38               MOV A,R3        ;RESTORE ACCUMULATOR
 0020 E7           39               RL A            ;MOVE BIT IN ACCUM TO LEFT
 0021 0419         40               JMP TSTUT       ;REPEAT TEST
                   41
                   42         ;RAM LOAD SUBROUTINE
                   43         ;IF HYDRAULIC SWITCH IS OFF A "1"IS LOADED IN ADDRESS
                   44         ;1.TEMPERATURE IN ADDRESSES 2 & 3 AND DISPLACEMENT
                   45         ;IN ADDRESSES 4 & 5.
 0023 2302         46 RMLD:         MOV A,#02       ;ENABLE STATE OF HYDRAULIC SWITCH
 0025 39           47               OUTL P1,A       ;        TO BUS
 0026 08           48               INS A,BUS       ;AND INPUT TO ACCUMULATOR
 0027 1241         49               JB0 END1        ;IF A "1" HYD SW.ON ,NO OP
 0029 2308         50               MOV A,#08H      ;ELSE ENABLE TEMP A/D CONVERTER
 002B 34A8         51               CALL GONOGO     ;INPUT DATA TO ACCUM
 002D AB           52               MOV R3,A        ;AND STORE IN R3
```

1087-093W(2)

```
LOC  OBJ        SEQ        SOURCE STATEMENT

002E 2320        53               MOV A,#20H      ;ENABLE DISPLACEMENT A/D CONVERTER
0030 34A8        54               CALL GONOGO
0032 AC          55               MOV R4,A        ,AND STORE IN R4
0033 27          56               CLR A           ,ZERO ACCUM
0034 39          57               OUTL P1,A       ;DISABLE DATA FROM BUS
0035 AD          58               MOV R5,A        ,INITIAL CONDITIONS
0036 BE10        59               MOV R6,#10H     ,  "  "     "      "
0038 17          60               INC A           ;PUT A "1" IN ADDRESSED RAM
0039 344F        61               CALL WRITE      ,       POSITION 1
003B FB          62               MOV A,R3        ,GET TEMP DATA FROM R3
003C 3447        63               CALL BYTST      ;STORE IN RAM 2 & 3
003E FC          64               MOV A,R4        ,GET DISPLACEMENT DATA
003F 3447        65               CALL BYTST      ;STORE IN RAM 4 & 5
0041 00          66 END1:         NOP             ;LOOP UNTIL SWITCH IS RELEASED
0042 0441        67               JMP END1
                 68        ;AIR ROUTINE
                 69        ;THIS ROUTINE TESTS THE RESERVOIR TO SEE IF THERE
                 70        ;WAS AN EXCESS OF AIR . THIS IS DONE BY CHECKING FOR
                 71        ;A DISPLACEMENT OF 1 INCH OR MORE THAN WHERE IT SHOULD
                 72        ;BE FOR THIS PARTICULAR TEMPERATURE.
                 73
0044 27          74 AIR.          CLR A           ;0 IN A
0045 39          75               OUTL P1,A       ,CLEAR P1 FROM BUS
0046 AD          76               MOV R5,A        ;INITIAL CONDITIONS
0047 BE30        77               MOV R6,#30H     ,   "       "
0049 3464        78               CALL READ       ;GET DATA FROM RAM ADDRESS 1
004B 5310        79               ANL A,#10H      ;CHECK FOR A "1"
004D C674        80               JZ NOAIR        ,IF NO "1" GO TO NEXT ROUTINE
004F 27          81               CLR A
0050 02          82               OUTL BUS,A      ;PUT "0" ON BUS
0051 2331        83               MOV A,#31H      ;SET UP MEMORY ADDRESS 1
0053 3A          84               OUTL P2,A       ; "  "   "     "   "
0054 2351        85               MOV A,#51H      ;WRITE "0" IN RAM ADDRESS 1
0056 3A          86               OUTL P2,A       ,  "   "  "  "   "    "
0057 2331        87               MOV A,#31H      ,DISABLE MEMORY
0059 3A          88               OUTL P2,A       ;  "     "
005A 80          89               MOVX A,@R0      ;DISABLE BUS
005B 348A        90               CALL TMPCK      ,SUBROUTINE
005D 345C        91               CALL LSD        ;GET T0 FROM MEMORY
005F 347C        92               CALL MLTPLY     ;T1-T0=T1',T1'XSLOPE =R1'
0061 345C        93               CALL LSD        ,GET R0 FROM MEMORY
0063 AA          94               MOV R2,A        ,PUT R0 IN R2
0064 F9          95               MOV A,R1        ,GET R1' IN ACCUM
0065 349B        96               CALL RSTR       ;GET RES1'
0067 34B2        97               CALL SBTCT      ;RCALC-RACT
0069 B674        98               JF0 NOAIR       ; IF F0 RES1'<R0+R1'
006B BA0E        99               MOV R2,#0EH     ,AIR TOLERANCE
006D 34B2       100               CALL SBTCT      ,AIR' = 05 - RES1'
006F F674       101               JC NOAIR        ;IF C RES1' < TOLERANCE
0071 2307       102               MOV A,#07H      ,LIGHT AIR LAMP
0073 39         103               OUTL P1,A       ;  "     "     "
0074 0476       104 NOAIR.        JMP VLCTY       ,GO TO FLOW RATE SUBROUTINE
                105
                106        ,FLOW RATE SUBROUTINE
                107        ,WILL COUNT NUMBER OF PULSES FOR 1 SECOND TO GET FLOW RATE
```

1087-093W(3)

```
LOC  OBJ         SOURCE STATEMENT

0076 27      VLCTY.    CLR A
0077 39                OUTL P1,A          ;CLEAR COUNTER PB0
0078 2306              MOV A,#06H         ;SET UP PB1
007A 39                OUTL P1,A          ;ALLOW COUNTER TO COUNT
007B BA05              MOV R2,#05H        ;SET UP FOR 50 MILLISEC
007D 343B              CALL MS10          ;
007F 23C0              MOV A,#0C0H        ;SET UP PB2
0081 39                OUTL P1,A          ;LATCH VALUE
0082 0484              JMP RSRVR          ;GO TO RESERVOIR ROUTINE
             ;RESERVOIR ROUTINE
             ;CHECK THE TEMPERATURE IF ABOVE 250F LIGHT TEMP LAMP.
             ;CHECK DISPLACEMENT VERSUS TEMPERATURE VERSUS WHERE
             ;IT SHOULD BE AT THIS TEMPERATURE AND IF IT IS OUT
             ;OF TOLERANCE LIGHT THE LEVEL LAMP . IF IT IS FURTHER
             ;OUT OF TOLERANCE LIGHT THE LEAK LAMP ALSO.
0084 348A    RSRVR.    CALL TMPCK         ;SUBROUTINE
0086 232B              MOV A,#02BH        ;T0 =  CONSTANT
0088 347C              CALL MLTPLY        ;SUBROUTINE
008A BA34              MOV R2,#34H        ;RES0 =  CONSTANT
008C 349B              CALL RSTR          ;SUBROUTINE
008E 2A                XCH A,R2           ;EXCHANGE R  VALUES
008F 34B2              CALL SBTCT         ;RACT-RCALC
0091 F6A6              JC NOERR           ;R ABOVE VALUE
0093 BA05              MOV R2,#05H        ;TOL1 =  CONSTANT
0095 34B2              CALL SBTCT         ;IS RESULT OUT OF TOLERANCE?
0097 F6A6              JC NOERR           ;IF A CARRY NO ERROR
0099 2303              MOV A,#03H         ;ELSE LIGHT RESERVOIR
009B 39                OUTL P1,A          ;      LEVEL LAMP
009C 2305              MOV A,#05H         ;TOL2 =  CONSTANT
009E 2A                XCH A,R2           ;SWAP TOL2 AND REMAINDER
009F 34B2              CALL SBTCT         ;IS RESULT STILL OUT OF TOLERANCE?
00A1 F6A6              JC NOERR           ;IF A CARRY NO ERROR
00A3 2380              MOV A,#080H        ;ELSE LIGHT RESERVOIR
00A5 39                OUTL P1,A          ;       LEAK LAMP
00A6 04A8    NOERR.    JMP RAT            ;GO TO RAT ROUTINE
             ;RAT ROUTINE
             ;THIS ROUTINE SOLVES THE EQUATION
             ;
             ;PPR = (R/3850) X (530/(T + 460)) X PSYS
             ;
             ;PSYS = PRESSURE READING + TEMPERATURE CORRECTION FACTOR
             ;R = RESISTANCE IN OHMS
             ;3850 = RESISTANCE AT STP
             ;530 = 70 DEGREES F + 460 TO MAKE DEGREES RANKIN
             ;T = MEASURED TEMPERATURE IN DEGREES F
             ;
             ;FIRST WE SOLVE FOR PSYS,AND STORE RESULT IN MEMORY,THEN WE
```

1087-093W(4)

```
 LOC  OBJ         SEQ        SOURCE STATEMENT

                  163        ;PERFORM 2 DIVISIONS,THEN 2 MULTIPLICATIONS.WE THEN SUBTRACT
                  164        ;450 PSI FROM THE RESULT TO TEST IF OUR PRECHARGE PRESSURE IS ADEQUATE
                  165        ;FOR THE SYSTEM , IF NOT WE LIGHT THE RAT LAMP.
                  166
                  167
                  168
                  169
00A8 3400         170 RAT:           CALL PRSCLC      ;SOLVE FOR PSYS
00AA 2385         171                MOV A,#85H       ;PUT 400 INTO ACCUM
00AC 6E           172                ADD A,R6         ;ADD TO GET RANKIN
00AD E6B1         173                JNC NOCA         ;IF NO CARRY NO OVERFLOW
00AF 23FF         174                MOV A,#0FFH      ;ELSE PUT FF INTO CARRY
00B1 BAB1         175 NOCA:          MOV R2,#0B1H     ;PUT 530 R IN R2
00B3 B821         176                MOV R0,#21H      ;INITIALIZE TO ADDRESS 33
00B5 5400         177                CALL DIVIDE      ;PERFORM 530/(T + 460)
                  178                                 ;STORE T IN 34 & 35
00B7 2328         179                MOV A,#28H       ;GET DISPLACEMENT FROM
00B9 34A8         180                CALL GONOGO      ;    A/D CONVERTER
00BB AA           181                MOV R2,A         ;AND PUT IN R2
00BC 2378         182                MOV A,#78H       ;PUT 3850 INTO ACCUM
00BE 5400         183                CALL DIVIDE      ;PERFORM R/3850
                  184                                 ;STORE IN 36 & 37
00C0 27           185                CLR A            ;WANT 0 IN
00C1 AC           186                MOV R4,A         ;R4 AND
00C2 AD           187                MOV R5,A         ;R5
00C3 B820         188                MOV R0,#20H      ;ADDRESS 32
00C5 F0           189                MOV A,@R0        ;MSBYTE OF PRESSURE
00C6 AE           190                MOV R6,A         ;TO R6
00C7 18           191                INC R0           ;ADDRESS 33
00C8 F0           192                MOV A,@R0        ;LSBYTE OF PRESSURE
00C9 AF           193                MOV R7,A         ;TO R7
00CA 18           194                INC R0           ;ADDRESS 34
00CB F0           195                MOV A,@R0        ;MSBYTE OF TEMP
00CC C6D2         196                JZ NOMLT         ;IF 0 NO MULTIPLY
00CE FE           197                MOV A,R6         ;MSBYTE OF PRESS
00CF AC           198                MOV R4,A         ;TO R4
00D0 FF           199                MOV A,R7         ;LSBYTE OF PRESSURE
00D1 AD           200                MOV R5,A         ;TO R5
00D2 18           201 NOMLT:         INC R0           ;ADDRESS 35
00D3 F0           202                MOV A,@R0        ;LSBYTE OF TEMP
00D4 5438         203                CALL QUADM       ;MULTIPLY TEMP AND PRESS
00D6 18           204                INC R0           ;ADDRESS 36
00D7 F0           205                MOV A,@R0        ;MSBYTE
00D8 C6DD         206                JZ NMLT1         ;IF 0 CONTINUE
00DA FE           207                MOV A,R6         ;MSBYTE TO A
00DB 04E1         208                JMP NMLT2        ;NO MULTIPLY
00DD 18           209 NMLT1:         INC R0           ;ADDRESS 37
00DE F0           210                MOV A,@R0        ;LSBYTE OF DISPLACEMENT
00DF 5438         211                CALL QUADM       ;MULTIPLY PREV RESULT
00E1 53FF         212 NMLT2:         ANL A,#0FFH      ;WANT TO CHECK Z FLAG
00E3 96F0         213                JNZ END2         ;GREATER THAN 512
00E5 FF           214                MOV A,R7         ;LSBYTE OF PPR
00E6 AA           215                MOV R2,A         ;PUT IN R2
00E7 23B6         216                MOV A,#0B6H      ;PUT 400 INTO A
00E9 34B2         217                CALL SBTCT       ;REMAINDER - 400
```

1087-093W(5)

```
 LOC  OBJ         SEQ         SOURCE STATEMENT

 00EB F6F0         218                  JC END2          ;IF CARRY REM>400
 00ED 2304         219 END3:            MOV A,#04H       ;ADDRESS RAT LAMP
 00EF 39           220                  OUTL P1,A        ;TURN IT ON
 00F0 0441         221 END2:            JMP END1         ;FINISHED
                   222
 0100              223            ORG 0100H
                   224            ;PRESSURE CALCULATION
                   225            ;THIS CALCULATION TAKES THE PRESSURE READING IN MV,TAKES
                   226            ;A TEMPERATURE READING ,ADDS OR SUBTRACTS A TEMPERATURE
                   227            ;CORRECTION TO AN INITIAL SLOPE READING,MULTIPLIES THE NEW
                   228            ;SLOPE BY THE MV READING AND ADDS AN INITIAL OFFSET.THE MSBYTE
                   229            ;IS STORED IN R5,AND THE LSBYTE IN R3.
                   230            ;POSITIVE TEMPERATURE
                   231            ;PRESSURE = (21 + (3T')X0.011) X MV + 23
                   232            ;NEGATIVE TEMPERATURE
                   233            ;PRESSURE = (21 - (3T')X0.017) X MV + 23
                   234
 0100 2330         235 PRSCLC:          MOV A,#30H       ;GET PRESSURE DATA FROM
 0102 34A8         236                  CALL GONOGO      ;     A/D CONVERTER
 0104 A8           237                  MOV R0,A         ;SAVE VALUE
 0105 BA0A         238                  MOV R2,#0AH      ;429 PSI
 0107 34B2         239                  CALL SBTCT       ;429 - P
 0109 E60D         240                  JNC END4         ;IF CARRY P < 429
 010B 04ED         241                  JMP END3         ;LIGHT LAMP
 010D F8           242 END4:            MOV A,R0         ;GET VALUE BACK
 010E AF           243                  MOV R7,A         ;STORE
 010F 2310         244                  MOV A,#10H       ;GET TEMPERATURE DATA FROM
 0111 34A8         245                  CALL GONOGO      ;     A/D CONVERTER
 0113 AE           246                  MOV R6,A         ;STORE
 0114 AA           247                  MOV R2,A         ;  "   ALSO IN R2
 0115 232B         248                  MOV A,#2BH       ;GET 70 F IN ACCUM
 0117 34B2         249                  CALL SBTCT       ;T-70 = T'
 0119 77           250                  RR A             ;
 011A 77           251                  RR A             ;
 011B 77           252                  RR A             ;
 011C 77           253                  RR A             ;DIVIDE BY 16
 011D 530F         254                  ANL A,#0FH       ;4 SHIFTS SHOULD BE 0
 011F B629         255                  JF0 NTMPTR       ;IF NEGATIVE TEMPERATURE
 0121 77           256                  RR A             ;ELSE DIVIDE BY 32
 0122 5307         257                  ANL A,#07H       ;5 SHIFTS SHOULD BE 0
 0124 0316         258                  ADD A,#16H       ;ADD 22 TO DELTA
 0126 AD           259                  MOV R5,A         ;SAVE IN R5
 0127 242E         260                  JMP MVMPLY       ;GO TO MULTIPLY
 0129 BA16         261 NTMPTR:          MOV R2,#16H      ;GET 22
 012B 34B2         262                  CALL SBTCT       ;22 MINUS DELTA
 012D AD           263                  MOV R5,A         ;SAVE IN R5
 012E FF           264 MVMPLY:          MOV A,R7         ;GET MILLI VOLTS
 012F AA           265                  MOV R2,A         ;AND PUT IN R2
 0130 FD           266                  MOV A,R5         ;GET DELTA
 0131 A9           267                  MOV R1,A         ;AND PUT IN R1
 0132 34BD         268                  CALL BMPY        ;MULTIPLY
 0134 B820         269                  MOV R0,#20H      ;ADDRESS #32
 0136 A0           270                  MOV @R0,A        ;MSBYTE IN 32
 0137 18           271                  INC R0           ;ADDRESS #33
 0138 F9           272                  MOV A,R1         ;GET LSBYTE
```

1087-093W(6)

```
LOC  OBJ         SEQ        SOURCE STATEMENT

0139 A0                                MOV @R0,A          ;STORE IN 33
013A 83                                RET


                           ;10 MILLISECOND SUBROUTINE
                           ;THIS SUBROUTINE USES THE 8748 BUILT IN TIMER. THE
                           ;T COUNTER IS LOADED TO 80HCH .
                           ;THIS GIVES A 10 MILLISECOND COUNTDOWN.EACH TIME WE
                           ;REACH COUNTDOWN WE DECREMENT A COUNT IN R2 SO THAT
                           ;WE CAN GET MULTIPLES OF 10 MILLISECONDS.

013B 2380           MS10               MOV A,#80H
013D 62                                MOV T,A            ;LOAD MAX COUNT IN T,ALL 0'S
013E 55                                STRT T             ;START COUNTDOWN
013F 1643           CONT:              JTF DECR           ;LOOP FOR 10 MILLISECONDS
0141 243F                              JMP CONT           ; "    "   "        "
0143 65             DECR               STOP TCNT          ;STOP COUNTER
0144 EA3B                              DJNZ R2,MS10       ;LOOP TILL R2 = 0
0146 83                                RET



                           ;BYTE STORE SUBROUTINE
                           ;BYTE STORE TRANSFERS THE FIRST 4 BITS INTO THE NEXT RAM
                           ;ADDRESS , THEN THE SECOND 4 BITS INTO THE NEXT RAM ADDRESS.

0147 A8             BYTST:             MOV R0,A           ;STORE VALUE IN R0
0148 344F                              CALL WRITE         ;WRITE LSD INTO MEMORY
014A F8                                MOV A,R0           ;GET WORD BACK INTO ACCUMULATOR
014B 47                                SWAP A             ;PUT MSD INTO LSD POSITION
014C 344F                              CALL WRITE         ;WRITE MSD INTO MEMORY
014E 83                                RET


                           ;WRITE SUBROUTINE
                           ;WRITE DATA INTO RAM. FIRST PUT DATA ON BUS WITH CE1',OD,
                           ;AND RW ALL HIGH. THEN ADDRESS WITH ONLY OD HIGH. THEN ADDRESS
                           ;WITH ALL HIGH TO TURN OFF MEMORY.R6 HAS 10H STORED AS AN
                           ;INITIAL CONDITION
014F 02             WRITE:             OUTL BUS,A         ;OUTPUT DATA ON BUS
0150 1D                                INC R5             ;GET NEXT ADDRESS
0151 FD                                MOV A,R5           ;PUT INTO ACCUM
0152 4E                                ORL A,R6           ;PUT A 1 IN FRONT OF ADDRESS
0153 3A                                OUTL P2,A          ;OUTPUT TO MEMORY
0154 4350                              ORL A,#50H         ;TURN ON WRITE
0156 3A                                OUTL P2,A          ;AND OUTPUT TO MEMORY
0157 531F                              ANL A,#1FH         ;PUT 1 IN FRONT OF ADDRESS
0159 3A                                OUTL P2,A          ;OUTPUT TO MEMORY
015A 80                                MOVX A,@R0         ;PUT BUS IN TRI STATE
015B 83                                RET

                           ;LSD SUBROUTINE
                           ;THIS SUBROUTINE GOES TO MEMORY AND FETCHES A NIBBLE AND
                           ;STORES IT.IT THEN GETS THE SECOND NIBBLE COMBINES THEM
                           ;AND WE GET THE WHOLE BYTE
```

```
 LOC  OBJ         SEQ        SOURCE STATEMENT

0150 3464          LSD:         CALL READ       ;GET LSD
015E 47                         SWAP A          ;PUT LSD IN LSD POSITION
015F A8                         MOV R0,A        ;STORE IN R0
0160 3464                       CALL READ       ;GET MSD
0162 48                         ORL A,R0        ;PUT BYTE TOGETHER
0163 83                         RET

                          ;READ SUBROUTINE
                          ;READ DATA OUT OF RAM. INITIAL CONDITIONS R5=00 ;,R6=30

0164 80            READ:        MOVX A,@R0      ;DISABLE BUS
0165 27                         CLR A           ;ZERO ACCUM
0166 39                         OUTL P1,A       ;CLEAR BUS
0167 1D                         INC R5          ;GET NEXT ADDRESS
0168 FD                         MOV A,R5        ;PUT INTO ACCUM
0169 4E                         ORL A,R6        ;PUT A 3 IN FRONT OF ADDRESS
016A 3A                         OUTL P2,A       ;AND OUTPUT TO RAM
016B 532F                       ANL A,#2FH      ;ENABLE READ
016D 4340                       ORL A,#40H      ;60 IN FRONT OF ADDRESS
016F 3A                         OUTL P2,A       ;  "      "
0170 08                         INS A,BUS       ;GET WORD FROM RAM
0171 08                         INS A,BUS       ;TWICE
0172 53F0                       ANL A,#0F0H     ;MASK OUT LSD
0174 AF                         MOV R7,A        ;STORE IN R7
0175 FD                         MOV A,R5        ;GET ADDRESS BACK
0176 4E                         ORL A,R6        ;PUT 7 IN FRONT OF ADDRESS
0177 533F                       ANL A,#3FH      ;3 IN FRONT OF ADDRESS
0179 3A                         OUTL P2,A       ;TURN OFF MEMORY
017A FF                         MOV A,R7        ;PUT WORD BACK IN ACCUM
017B 83                         RET

                          ;MULTIPLY SUBROUTINE
                          ;MULTIPLY SUBTRACTS T0 IN ACCUM FROM T1 IN R2 TAKES THE
                          ;DIFFERENCE AND MULTIPLIES IT BY CONSTANT (SLOPE) TO GET
                          ;DELTA RESISTANCE . CONSTANT = 3/8.
                          ;FIRST DIVIDE BY 8 THEN MULTIPLY BY 2 AND ADD 1


017C 34B2          MLTPLY:      CALL SBTCT      ;T1-T0=T'
017E B903                       MOV R1,#03H     ;NEED 3 SHIFTS
0180 97            MULT:        CLR C           ;SET CARRY = 0
0181 67                         RRC A           ;DIVIDE BY 2
0182 E930                       DJNZ R1,MULT    ;DIVIDE 3 TIMES
0184 A9                         MOV R1,A        ;STORE RESULT IN R1
0185 97                         CLR C           ;SET CARRY = 0
0186 F7                         RLC A           ;MULTIPLY BY 2
0187 69                         ADD A,R1        ;AND ADD 1
0188 A9                         MOV R1,A        ;STORE IN R1
0189 83                         RET

                          ;TMPCK SUBROUTINE
                          ;GETS TEMPERATURE DATA FROM A/D (FOR RESERVOIR AND AIR
                          ;CHECKS) TESTS TO SEE IF IT IS ABOVE 250F (= 121C). IF
                          ;IT IS TOO HIGH WE LIGHT THE TEMP LAMP
```

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```
LOC  OBJ          SEQ         SOURCE STATEMENT

                   383
018A 2308          384 TMPCK.         MOV A,#08H      ;CALL T1 A/D CONVERTER
018C 34A8          385                CALL GONOGO     ;GET T1 DATA
018E AB            386                MOV R3,A        ;SAVE IN R3
018F BA68          387                MOV R2,#68H     ;68 = 121C=250F
0191 34B2          388                CALL SBTCT      ;121-T1
0193 F698          389                JC EXCH         ;IF CARRY T1<250F
0195 2340          390                MOV A,#40H      ;ELSE ENABLE TEMP LAMP
0197 39            391                OUTL P1,A       ;LIGHT IT
0198 2B            392 EXCH           XCH A,R3        ;GET T1 FROM R3
0199 2A            393                XCH A,R2        ;PUT IT IN R2
019A 83            394                RET
                   395
                   396
                   397         ;RESISTOR SUBROUTINE
                   398         ;FINDS CALCULATED VALUE OF RESISTANCE AND SUBTRACTS IT FROM
                   399         ;ACTUAL VALUE
                   400
019B B6A1          401 RSTR.          JF0 SBRTN       ;IF F0 IS SET WE HAVE TO SUBTRACT
019D 6A            402                ADD A,R2        ;ELSE WE ADD
019E AA            403                MOV R2,A        ;STORE IN R2
019F 24A3          404                JMP FINI        ;ADDITION COMPLETE
01A1 34B2          405 SBRTN.         CALL SBTCT      ;STEP 1 ABOVE
01A3 2320          406 FINI.          MOV A,#20H      ;GET ACTUAL R FROM A/D
01A5 34A8          407                CALL GONOGO     ;AND PUT IN ACCUM
01A7 83            408                RET
                   409
                   410
                   411
                   412
                   413         ;GONOGO SUBROUTINE
                   414         ;THIS SUBROUTINE ENABLES THE SELECTED A/D CONVERTER
                   415         ;TO PUT DATA ON THE BUS.THE DATA VALID OUTPUT OF THE A/D
                   416         ;IS CHECKED AND DATA IS ACCEPTED IF TRUE.
                   417
01A8 39            418 GONOGO.        OUTL P1,A       ;SELECT A/D CONVERTERS
01A9 08            419 NOK            INS A,BUS       ;INPUT DATA FROM BUS
01AA 08            420                INS A,BUS       ;TWICE
01AB F2AF          421                JB7 OK          ;CHECK BIT 7 DATA VALID BIT
01AD 24A9          422                JMP NOK         ;IF NOT VALID GET NEW DATA
01AF 537F          423 OK.            ANL A,#7FH      ;IF OK MASK OUT MSB
01B1 83            424                RET
                   425
                   426         ;SUBTRACT SUBROUTINE
                   427         ;SUBTRACTS NUMBER IN ACCUMULATOR FROM NUMBER IN REGISTER R2
                   428         ;AND STORES THE RESULT IN R2. FLAG F0 IS "0" FOR POSITIVE
                   429         ;RESULTS AND "1" FOR  NEGATIVE.
                   430
01B2 85            431 SBTCT.         CLR F0          ;SET FLAG F0 TO 0
01B3 37            432                CPL A           ;COMPLEMENT ACCUM
01B4 6A            433                ADD A,R2        ;AND ADD TO R2
01B5 F6BF          434                JC PLUS         ;IF A CARRY RESULT IS PLUS
01B7 95            435                CPL F0          ;SET FLAG F0 TO "1"
01B8 37            436                CPL A           ;COMPLEMENT ANSWER
01B9 07            437                DEC A           ;SUBTRACT 1 AS WE ADD 1 NEXT STEP
```

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LOC  OBJ         SEQ         SOURCE STATEMENT

01BA 17           438 PLUS        INC A             ;ADD 1 TO GET CORRECT ANSWER
01BB AA           439             MOV R2,A          ;STORE ANSWER IN R2
01BC 83           440             RET               ;RETURN
                  441
                  442
                  443         ;BINARY MULTIPLY SUBROUTINE
                  444         ;THIS ROUTINE ASSUMES A 1-BYTE MULTIPLIER AND A 1-BYTE
                  445         ;MULTIPLICAND. THE PRODUCT THEREFORE IS 2 BYTES LONG.
                  446         ;THE ALGORITHM FOLLOWS THESE STEPS.
                  447         ;(1) THE REGISTERS ARE ARRANGED AS FOLLOWS .
                  448         ;       ACC = 0
                  449         ;       R1 = MULTIPLIER
                  450         ;       R2 = MULTIPLICAND
                  451         ;       R3 = LOOP COUNTER (=8)
                  452         ;THE ACCUMULATOR AND REGISTER R1 ARE TREATED AS A REGISTER
                  453         ;PAIR WHEN THEY ARE SHIFTED RIGHT.
                  454         ;(2) THE ACCUMULATOR AND R1 ARE SHIFTED RIGHT 1 PLACE ,THUS THE
                  455         ;LSB OF THE MULTIPLIER GOES INTO THE CARRY
                  456         ;(3) THE MULTIPLICAND IS ADDED TO THE ACCUMULATOR IF THE CARRY
                  457         ;BIT IS A '1'. NO ACTION IF CARRY IS A '0'.
                  458         ;(4) DECREMENT THE LOOP COUNTER AND LOOP (RETURN TO STEP 2) UNTIL
                  459         ;IT REACHES ZERO.
                  460         ;(5) SHIFT  THE RESULT RIGHT 1 LAST TIME JUST BEFORE EXITING
                  461         ;THE ROUTINE
                  462
                  463         ;THE RESULTS WILL BE FOUND MSBYTE IN THE ACCUMULATOR AND
                  464         ;LSBYTE IN R1.
01BD BB08         465 BMPY:       MOV R3,#08H       ;SET LOOP COUNTER TO 8
01BF 27           466             CLR A             ;CLEAR ACCUMULATOR
01C0 97           467             CLR C             ;CLEAR CARRY BIT
01C1 34CB         468 BMP1:       CALL DBLRT        ;DOUBLE SHIFT RIGHT ACC
                  469                               ;AND R1 INTO CARRY
01C3 E6C6         470             JNC BMP2          ;IF CARRY = 1 ADD ELSE DON'T
01C5 6A           471             ADD A,R2          ;ADD MULTIPLICAND TO ACCUMULATOR
01C6 EBC1         472 BMP2:       DJNZ R3,BMP1      ;DECREMENT LOOP COUNTER AND
                  473                               ;LOOP IF NOT ZERO
01C8 34CB         474             CALL DBLRT
01CA 83           475             RET
                  476
                  477
                  478
01CB 67           479 DBLRT:      RRC A             ;ROTATE RIGHT THRU CARRY
01CC 29           480             XCH A,R1          ;GET R1 IN ACCUM
01CD 67           481             RRC A
01CE 29           482             XCH A,R1          ;PUT R1 BACK
01CF 83           483             RET
                  484
                  485
                  486
                  487         ;DIVIDE ROUTINE
                  488         ;WE DIVIDE A 16 BIT DIVIDEND BY AN 8 BIT DIVISOR.
                  489         ;MSBYTE OF DIVIDEND IS IN R2
                  490         ;LSBYTE OF DIVIDEND IS IN R3
                  491         ;DIVISOR IS IN THE ACCUMULATOR
                  492         ;WE CHECK FOR THE FIRST '1' IN THE DIVISOR WHICH TELLS US HOW
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 LOC  OBJ         SEQ        SOURCE STATEMENT

                  493     ;MANY DIVISIONS. WE ADD THE 2'S COMPLEMENT OF THE DIVISOR TO
                  494     ;THE DIVIDEND. THE RESULTING CARRY IS SHIFTED INTO THE LSB
                  495     ;POSITION OF THE LSBYTE. THAT RESULTING CARRY IS SHIFTED INTO
                  496     ;THE LSB POSITION OF THE MSBYTE. THE F INAL ANSWER IS STORED
                  497     ;IN MEMORY
0200              498     ORG 0200H
0200 BB00         499 DIVIDE:      MOV R3,#0        ;CLEAR R3
0202 BD00         500              MOV R5,#0        ;CLEAR R5
0204 85           501              CLR F0           ;CLEAR FLAG F0
0205 97           502              CLR C            ;CLEAR CARRY
0206 B906         503              MOV R1,#08H      ;INITIAL # OF DIVIDE STEPS
0208 C630         504              JZ X7            ;WANT TO AVOID DIVIDE BY 0
020A F7           505 X1:          RLC A            ;WANT FIRST '1' SO WE KNOW
020B 19           506              INC R1           ;HOW MANY DIVIDE STEPS
020C 1D           507              INC R5           ;SAME AS ABOVE
020D E60A         508              JNC X1           ;FIRST ONE
020F 67           509              RRC A            ;RETURN '1' TO ACCUM
0210 37           510              CPL A            ;1'S COMPLEMENT
0211 17           511              INC A            ;2'S COMPLEMENT
0212 AC           512              MOV R4,A         ;SAVE DIVISOR
0213 27           513              CLR A
0214 97           514 X6:          CLR C
0215 A7           515              CPL C
0216 F7           516              RLC A
0217 ED14         517              DJNZ R5,X6
0219 AE           518              MOV R6,A
021A FC           519              MOV A,R4
021B 6A           520 X2:          ADD A,R2         ;SUBTRACT DIVISOR FROM DIVIDEND
021C B620         521              JF0 X5           ;IF FLAG SET WAS A CARRY
021E E623         522              JNC X3           ;IF NO CARRY NO CHANGE
0220 97           523 X5:          CLR C            ;WANT TO SET CARRY TO 1
0221 A7           524              CPL C
0222 AA           525              MOV R2,A         ;ELSE PUT NEW RESULT IN R2
0223 FB           526 X3:          MOV A,R3         ;LSBYTE IN ACCUM
0224 F7           527              RLC A            ;SHIFT CARRY INTO LSB
0225 AB           528              MOV R3,A         ;PUT BACK
0226 85           529              CLR F0           ;CLEAR FLAG F0
0227 FA           530              MOV A,R2         ;MSBYTE IN ACCUM
0228 F7           531              RLC A            ;SHIFT CARRY INTO LSB
0229 E62C         532              JNC X4           ;NO CARRY DON'T SET F0
022B 95           533              CPL F0           ;IF CARRY SET F0
022C AA           534 X4:          MOV R2,A         ;PUT BACK
022D FC           535              MOV A,R4         ;GET DIVISOR BACK
022E E91B         536              DJNZ R1,X2       ;CONTINUE DIVISION
0230 FE           537 X7:          MOV A,R6
0231 5A           538              ANL A,R2
0232 18           539              INC R0           ;GET NEXT MEMORY POSITION
0233 A0           540              MOV @R0,A        ;STORE IN MEMORY
0234 18           541              INC R0           ;NEXT MEMORY LOCATION
0235 FB           542              MOV A,R3         ;LSBYTE TO ACCUM
0236 A0           543              MOV @R0,A        ;AND STORE IN MEMORY
0237 83           544              RET
                  545
                  546
                  547 ;QUAD MULTIPLY
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1087-093W(11)

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 LOC  OBJ              SOURCE STATEMENT

              ;FIRST MULTIPLY # AND R7 (LSBYTE) DROP LSBYTE OF RESULT
              ;AND ADD MSBYTE OF RESULT TO R5.
              ;THEN MULTIPLY # AND R6 (MSBYTE). ADD LSBYTE OF RESULT
              ;TO R5 AND MSBYTE OF RESULT TO R4.


 0238 AA      QUADM:          MOV R2,A         ;GET MULTIPLIER IN R2
 0239 FF                      MOV A,R7         ;LSBYTE
 023A A9                      MOV R1,A         ;TO R1
 023B 34BD                    CALL BMPY        ;MULTIPLY
 023D 6D                      ADD A,R5         ;ADD MSBY OF CALC TO R5
 023E AD                      MOV R5,A         ;STORE IN R5
 023F E642                    JNC Y1           ;IF CARRY
 0241 1C                      INC R4           ;ADD 1 TO R4
 0242 FE      Y1:             MOV A,R6         ;MSBYTE
 0243 A9                      MOV R1,A         ;TO R1
 0244 34BD                    CALL BMPY        ;MULTIPLY
 0246 29                      XCH A,R1         ;MSBY TO R1 LSBY TO A
 0247 6D                      ADD A,R5         ;ADD LSBYTES
 0248 BD00                    MOV R5,#0H       ;CLEAR R5
 024A AF                      MOV R7,A         ;RESULT TO R7
 024B E64E                    JNC Y2           ;IF CARRY
 024D 1C                      INC R4           ;ADD 1 TO MSBY
 024E F9      Y2:             MOV A,R1         ;MSBYTE TO A
 024F 6C                      ADD A,R4         ;ADD MSBYTES
 0250 BC00                    MOV R4,#0H       ;CLEAR R4
 0252 AE                      MOV R6,A         ;RESULT TO R7
 0253 83                      RET






                              END

USER SYMBOLS
AIR    0044  BMP1   01C1  BMP2   01C6  BMPY   01BD  BYTST  0147  CONT   013F  DBLRT  01CB  DECR   0143
DIVIDE 0200  END1   0041  END2   00F0  END3   00ED  END4   010D  EXCH   0198  FINI   01A3  GONOGO 01A8
LSD    015C  MLTPLY 017C  MS10   013B  MULT   0180  MVMPLY 012E  NMLT1  00DD  NMLT2  00E1  NOAIR  0074
NOCA   0081  NOERR  00A6  NOK    01A9  NOMLT  00D2  NTMPTR 0129  OK     01AF  PLUS   01BA  PRSCLC 0100
QUADM  0238  RAT    00A8  READ   0164  RMLD   0023  RSRVR  0084  RSTR   019B  SBRTN  01A1  SBTCT  01B2
SONCE  0014  START  0002  TMPCK  018A  TSTUT  0019  VLCTY  0076  WRITE  014F  X1     020A  X2     021B
X3     0223  X4     022C  X5     0220  X6     0214  X7     0230  Y1     0242  Y2     024E

ASSEMBLY COMPLETE,   NO ERRORS
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1087-093W(12)

@@ @@ A077552 (U) FIELD/GROUP @@@@@@

UNCLASSIFIED TITLE

HYDRAULIC DIAGNOSTIC MONITORING SYSTEM.

ABSTRACT

(U) THE PURPOSE OF THE HYDRAULIC DIAGNOSIC MONITORING SYSTEM (HYCOS) I
EM COMPONENTS BY ONBOARD SENSORS CONTINUOUSLY MONITORING FAILURE-INDIC
OF THREE BASIC TYPES OF SENSORS: ANALOG, DISCRETE, AND FIBER-OPTIC. TH
CENTRALLY LOCATED DISPLAY PANEL THROUGH INTERFACE CIRCUITS THAT ARE E
THE PAEL HAS CIRCUIT AND SYSTEM TEST CAPABILITY WHICH DETECTS MALFUNC
MENT, AND SENSOR CIRCUITS. TASK I ENCOMPASSED THE DESIGN, DEVELOPMENT
CESSORS FOR TWO DIAGNOSTIC MONITORING SYSTEMS. TASK II INSTALLED ONE S
M COMPONENT RELIABILITY DEMONSTRATIONS. THE TASK ALSO COVERED SIMULATE
ON.

INDEX TERMS ASSIGNED

DISPLAY SYSTEMS	PANELS
ELECTRONIC EQUIPMENT	HYDRAULIC
CIRCUITS	INTERFACES
MALFUNCTIONS	MICROPROCES
MONITORS	DETECTORS

TERMS NOT FOUND ON NLD

COVERED SIMULATED COMPONENT FAILURES	DIAGNOSTIC
DIAGNOSTIC SYSTEM REACTION	GROUND MAI
HYDRAULIC DIAGNOSTIC MONITORING SYSTEM	HYDRAULIC
SENSOR CIRCUITS	SENSORS FE
SYSTEM COMPONENT RELIABILITY DEMONSTRATIONS	SYSTEM TES

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IC MONITORING SYSTEM (HYCOS) IS TO WARN OF IMPENDING FAILURE OF HYDRAULIC SYST
USLY MONITORING FAILURE-INDICATING PARAMETERS. THE MONITORING SYSTEM CONSISTS
DISCRETE, AND FIBER-OPTIC. THESE SENSORS FEED INFORMATION TO A SELF-CONTAINED,
INTERFACE CIRCUITS THAT ARE EASILY ACCESSIBLE TO GROUND MAINTENANCE PERSONNEL.
ABILITY WHICH DETECTS MALFUNCTIONS OF THE DISPLAY INDICATORS, ELECTRONIC EQUIP
SSED THE DESIGN, DEVELOPMENT AND PROCUREMENT OF HARDWARE, SENSORS AND MICROPRO
TEMS. TASK II INSTALLED ONE SYSTEM ON THE F-14 A HYDRAULIC SIMULATOR FOR SYSTE
HE TASK ALSO COVERED SIMULATED COMPONENT FAILURES AND DIAGNOSTIC SYSTEM REACTI

INDEX TERMS ASSIGNED
PANELS
HYDRAULIC EQUIPMENT
INTERFACES
MICROPROCESSORS
DETECTORS

TERMS NOT FOUND ON NLDB
DIAGNOSTIC MONITORING SYSTEMS
GROUND MAINTENANCE PERSONNEL
HYDRAULIC SIMULATOR
SENSORS FEED INFORMATION
ONS SYSTEM TEST CAPABILITY